Andres Torres

Identifying Challenges and success factors towards Implementing Industry 4.0 technologies in the Shipbuilding Industry.

TU Delft Delft University of Technology

Identifying Challenges and success factors towards Implementing Industry 4.0 technologies in the Shipbuilding Industry.

Identification of challenges and success factors using explorative research approach based on interviews from Shipbuilding experts, Industry 4.0 experts and technology developers.

By

Andres Francisco Torres
(459-4444)

In partial fulfillment of the requirements for the degree of

Master of Science

In Management of Technology

At the Delft University of Technology,
To be defended in public on Friday August 31st, 2018.

Committee.

Dr. Robert Verburg (Chairman, Tu Delft-TPM)
Dr. Jan Anne Annema (Daily supervisor, Tu Delft-TPM)

Acknowledgements:

First, I would like to express my most profound gratitude to Pao and Isa, without them this dream would never have been possible, you two encouraged me in the worst moments for which I will always have the greatest gratitude. Second, thanks to my Father, Mother and Brothers who unconditionally gave me their support and love, always teaching me the importance of the value of perseverance and hard work that certainly played a significant role throughout this challenging journey. Last but not least to my grandparents Tata, Tita and Pacho (R.I.P) you left us but you will always have a special part in my heart for teaching me the importance of laughing at life.

I further extend my gratitude to my daily supervisor, J.A Annema and Chairman Robert Verburg who guided me through every step of the process with carefulness, scrupulousness and dedication teaching me the value of rigor in research.

Finally, I extend my gratitude to the group of experts that in a selfless way shared with me their knowledge and expertise during the interviews, always giving the best ideas to enrich the content of my thesis. And lastly, I would also like to mention all my friends from MoT, thank you all for your endless support.

I dedicate this thesis to Papi Pacho (R.I.P) (June-03-1930) (July-05-2018)

Executive Summary

Industry 4.0 refers to the allocation of several new technologies which are currently reshaping the manufacturing and process industry. These developments are expected to have a positive impact for many industries, driving processes towards leaner and more efficient standards. By considering the possible effect of Industry 4.0 technologies in the shipbuilding industry, the aim of this thesis was to discover the main challenges to the implementation of Industry 4.0 technologies in the shipbuilding Industry, and to examine the main success factors towards the implementation and final adoption of these technologies in the shipbuilding industry.

RQ1: *"What are the main challenges to adopting Industry 4.0 technologies in the Unique Product Shipyard Industry?"*
RQ2: "*What general recommendations should be given to a shipbuilding company to increase the chances of a successful implementation of Industry 4.0 technologies?"*

In this thesis a theoretical model TOE Frameworks developed by (Tornatzky, 1990) was used to assess the factors influencing the adoption of Industry 4.0 technologies in a shipbuilding setting. As is clear by the model acronym, these [adoption] factors were divided in three main categories: technology, organization, and the environment. Furthermore, explorative qualitative research was used to obtain the empirical data. This data was gathered by interviewing a group of experts from three main groups (Shipbuilding experts, Industry 4.0 and technology developers).

Results.

A rich view on issues and insights were obtained from a total of 22 interviews with experts, the interviews were done from the period of April/18 to May/18. The interviewees were selected from amongst a group of experts from three main fields: technology developers, Industry 4.0 experts and shipbuilding experts. The study identified seven main challenges found while implementing Industry 4.0 technologies in the shipbuilding Industry which are further explained in Chapter 6. The challenges that came to light were varied. They included: *Data Collection problems, the Uniqueness of the Shipbuilding Process, Cyber risk Understanding, Top management support,*

cultural structure, lack of resources and finally the implication of Government Policies. Each of these challenges was considered important by the group of experts, and helped to clarify the difficulties encountered by shipbuilding companies wishing to begin a transformation process towards the application of digitized technologies within the manufacturing process.

Table 1: General challenges obtained from the encoding scheme.

Category	***Subject***	***Code***
Technology (TECH)	Problems collecting data from production process	**TECH1**
	Shipbuilding depends on craftsmanship, building unique and one of a kind ships.	**TECH3**
	Understanding potential Cyber risk	**TECH6**
Organization. (ORG)	Top management support is necessary for stablishing any change.	**ORG1**
	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	**ORG2**
	Lack of resources	**ORG5**
Environment (ENV)	There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	**ENV2**

The study also yielded five factors seen in the successful adoption of Industry 4.0 technologies. The derived recommendations, as shown in (*table 2*), can be considered as a general roadmap for shipbuilding companies wishing to begin the transformation process towards digitized technologies related to Industry 4.0. Also, these findings show that technological barriers are not the only factors that have significant effects on the decision-making process of adopting an Industry 4.0 technology; organizational and environmental factors also play an important role in the process. It is also clear that many of the current processes and interactions within the shipbuilding industry will need to be changed to embrace the development of new technologies where complex hierarchical structures will be replaced by more organic structures characterized by cross-sectional teams working toward the development of Industry 4.0 technologies.

It can also be observed from the results of the coding scheme that the shipbuilding industry deviates considerably from other industries. Some of the engineering process present in the shipbuilding industry are comparable to those in other industries, but there are, nevertheless, many unique barriers because of specialized techniques and process used in the industry. Some of the barriers were mentioned by the group of shipbuilding experts.

Table 2: General success factors towards the implementation of Industry 4.0 technologies.

Category	***Subject***	***Code***
Technology (TECH)	Don't think about the technology first, think about the process.	**TECH2**
	Think about technology that enhance human performance, not replace them.	**TECH4**
	Start with small projects to have fast success then move to bigger projects.	**TECH5**
Organizational (ORG)	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology	**ORG4**
Environment (ENV)	Making strategic alliances	**ENV1**

In the results obtained in this thesis, it appeared that, even if there are many benefits from implementing Industry 4.0 technologies in the Shipbuilding Industry, there are still many challenges that need to be solved before it is possible to completely adopt these technologies. The study also shows that a combination of strategies can be used as a guide for a company beginning in the transformation process. The results represent a general perspective for a shipbuilding company wishing to begin the transformation process towards digitized technologies. The transformation process starts by mapping the current situation of the company and then developing a strategy that best fits the company's interests. Then, experts also recommend that companies think about their workers first, asking themselves how the technologies help their employees to become more efficient. Thirdly, companies should develop small projects that can enable them to demonstrate early success; thereby encouraging top management to continue investing in related Industry 4.0 technologies. Finally, companies should contemplate making organizational changes within their structure; as previously discussed, companies wishing to pursue innovation and adoption of new technologies generally require more flexible and agile structures.

Table of Contents:

List of Figures:

List of Tables:

1. Introduction.

Currently, across different industries, traditional manufacturing is in the throes of a digital transformation. This transformation is being accelerated by technologies that are continuously developing in an exponential manner. This pace of growth is represented by "Moores Law" which describes the speed at which technology-driven change happens. Therefore, companies find it necessary to adapt to this rapidly changing environment if they wish to avoid being left behind by competitors that do take advantage of these technologies (Deloitte, 2016). Getting a clear view of the general acceptance of these technologies across different industries is also relevant for the shipbuilding industry, in particular, to determine if it would eventually benefit from the introduction of these innovations. The objective of this thesis is to investigate the challenges and opportunities of adopting Industry 4.0 technologies in the Shipbuilding Industry.

The shipbuilding process is highly complicated, involving many stakeholders and disciplines in which parallel construction often takes place simultaneously in different locations on a single ship. The processes involved in shipbuilding are also very expensive and time consuming; new ships cost up to several hundreds of millions of dollars, and are built over a period ranging from months to years. Recently, specific macro-level factors such as the volatility in the price of fuel and the constant increase in environmental regulations are changing the process of designing and building of a ship. These factors have created a need for building ships in a more cost, and energy, efficient manner. The shipbuilding process consists of four principal phases: starting from the concept design, followed by contract design, preliminary design and finally the detail design. The processes entailed are iterative, taking many months to complete. Typically, shipyards rely on the experience of their engineers to complete this process, relying heavily upon CAD tools and Simulation Base Design (Hock, 2015). However, a new era of digitized production and engineering may challenge this form of production in the shipbuilding industry; this era is referred to as Industry 4.0, or the fourth Industrial Revolution (Deloitte, 2015).

The essence of Industry 4.0 is the introduction of Cyber-Physical Systems into industrial applications. The Cyber-Physical System is formed by sensors, objects and actuators that can

continuously communicate through the Internet of Things, creating, thereby, a Network of machines and products extending all the way through the value chain. This network enables the collection and analysis of massive amounts of data, often in real time. The Internet of Things also allows sharing information in real time, creating a network between different factories, people and machines that helps the manufacturing and building process to fulfil the dynamic requirements of production and to improve the overall effectiveness of the manufacturing process. Industry 4.0 encompasses many different technologies, such as Internet of things, Radio Frequency Identification, and cloud-based manufacturing and product development (Lu, 2017). As Roblek, (2015) described there are five significant features of Industry 4.0: digitization, automation and adaption, human-machine interaction, and Automatic data exchange and interaction. Every element of industry 4.0 is highly interconnected by the use of internet technologies and the involvement of sophisticated algorithms (Roblek, 2015).

Available literature offers insights into the adoption of Industry 4.0 in different manufacturing settings. However, during a thorough literature search using keywords such as: "Industry 4.0", "Shipbuilding" and "Internet of Things", limited information was found regarding the implementation of industry 4.0 technologies in the shipbuilding industry. Only a few sources were uncovered such as (NAVANTIA, 2015) and (Hock, 2015) . Furthermore, the complexity of the shipbuilding setting creates various problems for embedding new and innovative technologies. For this reason, available literature does not offer a clear insight into the impact of Industry 4.0 in the shipbuilding industry. The massive amounts of stored and produced data are not being used during manufacturing process, and most of the planning of work activities during the manufacturing process is done by using basic empirical formulas, or, in some cases, by slightly modifying previously scheduled activities based upon other ship data. This empirical approach makes for a very old-fashioned way to plan working activities (Chang, 2016). This type of outdated scheduling technique hinders improvement of processes and produces other problems during manufacturing that will be furtherly discussed. Furthermore, it is also worth considering that the adoption of technological innovations can allow shipbuilding companies to better cope with the rapidly changing dynamics of the industry.

To address the practical problem(s) highlighted by this quote, this thesis proposes…

"No matter the sector or region, in the future digitalization – as integrated and universal as possible – will here, as in other industries, be one of the requirements for achieving a leading position in the market or even for maintaining a competitive one. Traditional methods that still depend heavily on 2-D drawings and manual documentation are just not capable of keeping up the pace that is today expected in shipbuilding."

Bert Geisler, 2016.

To address this practical problem, this thesis proposes developing **"An exploratory study aimed at finding the challenges and opportunities surrounding the adoption of Industry 4.0 technologies in Shipbuilding."** The study starts by establishing the most relevant technologies methods and tools used in Industry 4.0, followed by current applications within industrial procedures, and then delves deeper into the implications for shipbuilding

The research will be directed towards Unique Product shipyards or (UPS). This type of shipbuilding company produces an extensive variety of products commonly ranging from small civilian and military boats to large luxury yachts. Such shipyards have different lifting and production capacities depending on the particular area in which they specialize. For this reason, during the research, any reference to UPS indicates the segment which builds ships that are one of a kind. Considering the specific requirements of the customer gives them the flexibility to modify and change the vessel as they please, examples of these types of vessels are luxury yachts and military ships. The ability of a customer to alter the ship design is the differentiating factor from so called "streamline shipyards", which are characterized by a steady line of production. In such shipbuilding companies the customer does not have the ability to modify the initial design of the vessel.

1.1 Research Formulation.

1.2 Problem statement.

In January 2015, *Mckinsey* conducted the second edition of its Industrial expert survey across 300 industry experts located in Germany, the United States, and Japan; posing 23 different questions relating to the importance of, and the degree of success achieved in, implementing Industry 4.0. The experts who participated in the survey came from the automotive industry, automotive part suppliers, the chemical industry, the software sector, transport and logistics providers, and the industrial equipment and automation industry. The survey gathered the following key results: Most experts (67%i n Germany and 74% in Japan) are optimistic about the potential of implementing Industry 4.0, and 90% stated that their competitiveness would increase and have an overall positive impact in their operational effectiveness. The results present a positive perception in the manufacturing industry. However, the report did not offer a clear insight into the effects and challenges of implementing Cyber-Physical systems in the shipbuilding industry. For this reason, the purpose of this report is to have a clear perspective of the main problems that arise, and the benefits that can be obtained, if Industry 4.0 technologies are implemented in the shipbuilding industry. (McKinsey&Company, 2015)

1.3 Research Objective:

Since the introduction of the term Industry 4.0 in the 2013, Hannover International Fair academics and researchers have discussed the many advantages and challenges towards implementing Cyber-Physical Systems across different industries. However, because of the high complexity of the Shipbuilding processes, there is still a knowledge gap that hinders the adoption of these technologies. Thus, the information gathered from examples of the adoption of techniques related to Industry 4.0 in the Unique Product Shipbuilding sector is limited regarding the challenges that these companies faced while embracing industry 4.0. Therefore, the study aims to develop a framework to assess the impact of the adoption of Industry 4.0 related technologies in the Unique Product Shipbuilding Industry.

1.4 Research Question.

"What are the main challenges and success factors towards adopting Industry 4.0 technologies in the Unique Product Shipyard Industry."

In this report, the main research question was answered by detailing three steps taken during the research process: First, an extensive literature review was conducted, and gave valuable insights into the factors that may play an important role in the adoption of Industry 4.0 technologies in the Shipbuilding industry such as: The Internet of Things and Cyber Physical Systems. This information, in combination with technological acceptance models, was used to develop questions for the interviews that were conducted with Industry 4.0 experts. Later on, the findings were analyzed using content analysis and finally conclusions were drawn regarding the expert's opinions and beliefs.

After coding the responses and finding saturation in the answers from the interviews, the opinions and recommendations gave a clear insight into the actual problems faced by the companies from which the interviewees came. In this report, the questions were answered in a sequential order; this method is intended to yield the critical insights needed to fulfill the main research objective. Sub-question 1 offered a general idea and the theoretical implications in the adoption of new technologies in the shipbuilding sector, while sub-question number 2 was intended to establish the scope and the applicability of industry 4.0 within the shipbuilding industry.

1.5 Academic relevance of the research:

The research proposal was aimed towards identifying the main challenges that unique Product Shipyards face while adopting Industry 4.0 Technologies, like Cyber-Physical Systems and Internet of Things, in their manufacturing processes. All of the main activities, from scoping the project to the development of a basic understanding of the scheduling process, are structured within the research so the results can be transferred to a shipbuilding company. The theory of technological acceptance was used to assess the adoption of Industry 4.0 at a firm level. As mentioned in the introduction section, Industry 4.0 has been applied successfully in other

industrial applications. However, the research of implementing technologies such as Cyber-physical Systems and IoT for specific applications within Shipyards that build Unique Products has been limited. Therefore, it is worthwhile to consider its implications in this segment of the shipbuilding industry. Moreover, an ancillary benefit is that the Netherlands is one of the countries that specializes in building UPS products like super-yachts.

1.6 Research Approach.

The structure of the report can be seen as an outline for the collection, measurement, and analysis of necessary data to give a grounded answer to the research question and to reach the objective of the study.

As is evidenced by the research question: ***"What are the main challenges and opportunities to the adoption of Industry 4.0 technologies in the Unique Product Shipyard Industry?"*** this study is exploratory in nature. According to Sekaran, (1998) an exploratory study is used when few facts are known about the subject that is being studied (Sekaran, 1998). Also, according to Burns and Bush (2006), an exploratory research design is defined as the process of gathering valuable information in both an informal and unstructured manner. The exploratory study is proper when the researchers know little about the phenomenon that is being studied. Exploratory research is not only limited to one specific paradigm, but may be used for either qualitative or quantitative research approaches. An exploratory study is a valuable means of seeking new insights; the methodology relies upon asking questions to asses the phenemonen with a new perspective. During the initial literature review not much information was found regarding the implementation of Industry 4.0 related technologies in the Shipbuilding Industry, thus the main purpose of the study is to find the main challenges of implementing Industry 4.0 related technologies in the shipbuilding Industry. The type of study selected is a perfect fit with the description of an exploratory study provided (Sekaran, 1998).

The thesis was divided into five sections. Section 1 Presents an introduction of the problem statement, research questions and sub-questions, the relevance and scope of the research and the methodology used. In section 2 the theoretical grounding concepts describe the main theoretical

models used for developing questions for the interviews where the empirical data was obtained. In Section 3 the actual technologies used in industry 4.0 in manufacturing that can be eventually transferred to a shipyard setting were introduced. In the same section, the opinions of Industry 4.0 experts selected for the interviews will be included to asses a possible timeline for inclusion of the technologies in the shipbuilding industry. Section 4 consists of a description of the methodology used in obtaining the data. Section 5 contains the findings from the encoding scheme. Finally, a reflection were made upon the research considering the limitations of the study.

1.6.1 Methodology.

The methodology used for the research consisted of 5 steps: preliminary analysis, a literature review, an extended literature review, industry 4.0 expert interviews, case studies analysis, and, finally, synthesis and analysis. Each step is supported by different research and data collection methods.

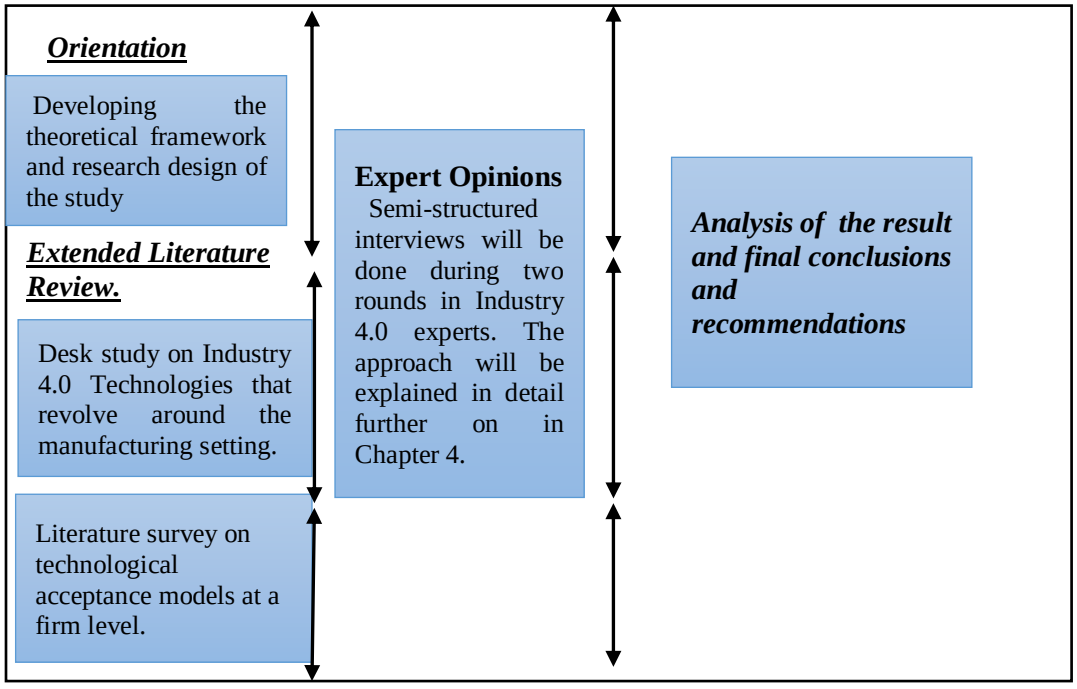

Figure 1:Research methodology steps.

1.6.2 Preliminary Analysis.

In this section, relevant literature was selected, this preliminary step gave a broader understanding of the implications of Industry 4.0 in manufacturing, and on its consequences in the Shipbuilding Industry. Also, an exploratory study was conducted to select possible candidates for the interviews, the selection was done using a convenience sample.

1.7 Orientation of the thesis

The literature review consists of an extensive survey of academic literature concerning Industry 4.0 related technologies, and rate of adoption of these technologies in the manufacturing sector. The initial literature review was used to define concepts that were used later on such as: Cyber-Physical Systems, Internet of Things, Big data analytics, and Automation in Shipbuilding.

1.7.1 literature Review.

During this research step, the theoretical concepts of Industry 4.0 were integrated within the applications and domain of shipyards. In this step, examples of successful applications of technologies related to industry 4.0 in manufacturing that can be transferred to the shipbuilding sector were discovered, and used to answer related research sub-questions. This was done by using systematic key words such as “Industry 4.0”, “Internet of Things for manufacturing”, “Smart Industry” and “Cyber Physical Web.

2.Theoretical Framework.

According to Wade, (2010) there are many theories regarding technological adoption and its involvement in the enhancement of the competiveness of a firm; therefore, it is important to understand the deterministic factors in Technological Adoption and the related theoretical models (Wade, 2010). The most common models used to assess technological adoption at an individual level are the Technological Adoption Model (TAM) developed by. (Davis, 1986), and the theory of planned behavior (TBP) developed by Ajzen (Ajzen, 1991). At the firm, or industry, level the most commonly used models are the Diffusion of Innovation Model (DOI) developed by Rogers (Rogers, 1995), and the Technological, Organization and Environment (TOE) context developed by Tornatzky and Fleischer (Tornatzky, 1990). The last two models are the only ones that will be used for the present thesis because they were developed with the sole purpose of being used at the firm or industrial level rather than at an individual or end-user level. They also involve environmental and organizational factors that can help to give insights about the adoption of Industry 4.0 technology in the shipbuilding industry.

2.1 Technology, Organization and Environment context. (TOE)

The Technology, Organization, and Environment framework, developed by Tornatzky, (1990) pinpoints three principal aspects in an industrial context that could eventually influence the adoption, and further implementation, of technological innovation (Tornatzky, 1990): a technological context, an organizational context and environmental context this concept illustrated below in (*Figure 2*).

These three categories are further specified as follows: (i) The technological context consists of both the external and the internal technologies relevant to the company, including the equipment and current practices of the firm, as well as the available technologies in the external environment (Thompson, 1997). (ii)The Organizational context refers to a descriptive analysis of the organization such as; managerial structure, firm size, and the scope of the firm's operations. (iii) The Environmental background refers to the context, or arena, in which the company conducts its

business, including factors such as competition, government and the greater industrial sector to which the company belongs (Tornatzky, 1990).

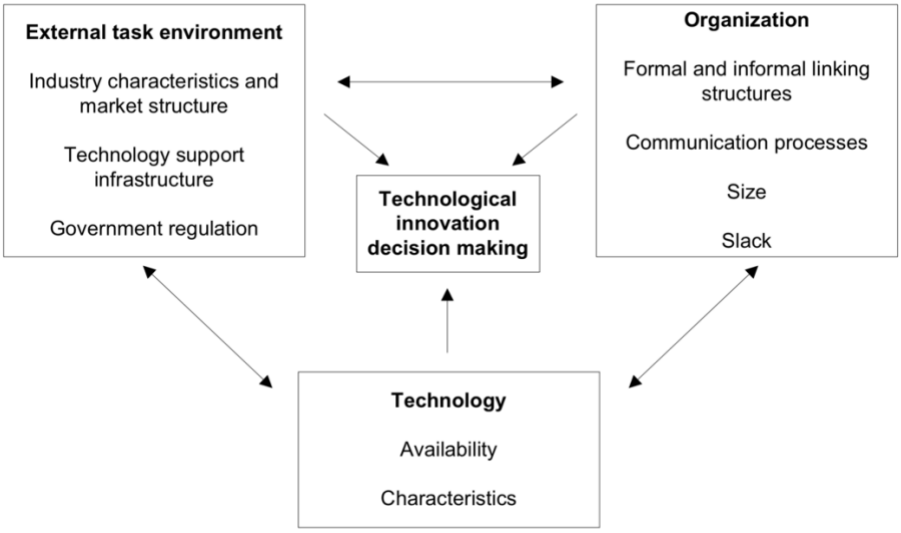

Figure 2: Technological, Organization and Environment framework. ***(Tornatzky, 1990)***

The TOE framework was initially developed for studies of IT adoption, and provides a complete analytical framework that can be used to study the adoption of different kind of technologies related to innovation within the setting of a company. The model also emphasizes that both internal and external characteristics are drivers for the adoption of a new technology, and the environmental context includes both the opportunities and constraints involved in technological innovation.

2.2 Diffusion of Innovations.

The Diffusion of Innovation theory revolves around how and why new technologies spread across different cultures and industries, as well as their rate of spread. The DOI theory describes innovation as part of a social system where technologies are communicated across different channels (Rogers, 1995). Thereby, firms and individuals are assumed to hold different positions regarding the adoption of technologies, thus Rogers discovered that the portion of the population adopting the technology is almost normally distributed in time. In his 1995 work, Rogers broke the distribution of segregation of adoption into five principal segments: Innovators, early adopters, early majority, late majority, and laggards. The process of transferring the model to organizations

is more complex as it involves different perceptive stances in support of, or opposition to the technologies, each playing an important role in the decision-making process (Oliveira, 2011).

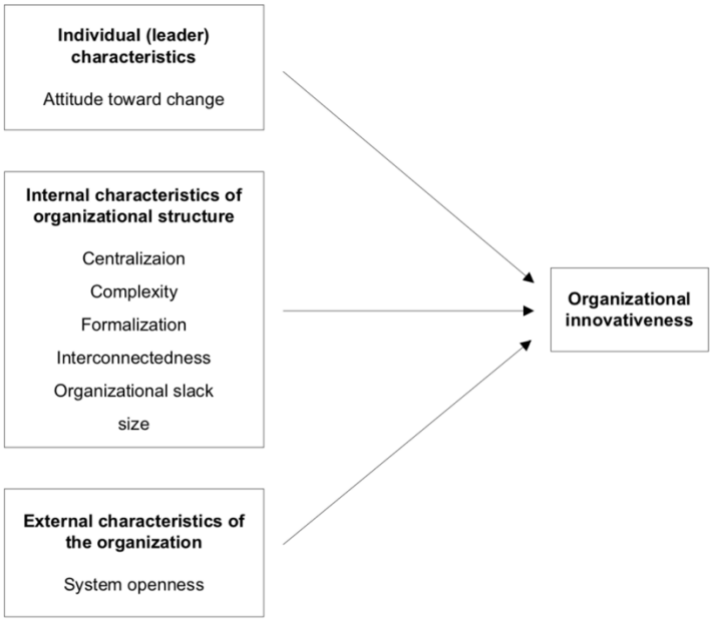

Figure 3: Diffusion of Innovation DOI model. ***(Rogers, 1995)***

Based on the Diffusion of Innovation theory, innovation is related to independent factors such as the internal structure of organizations, and the external characteristics of the organization. These factors are more specifically defined thus: (i) "Individual characteristics" describes the attitude towards change adopted by corporate leadership. (ii) "Internal characteristics of organizational structure" describes the degree of centralization, or the degree to which power is distributed across a limited number of individuals. "Complexity" refers to the knowledge and expertise certain individuals of the organization possess related to the technology in context. "Formalization" is the degree to which an organization is structured by a series of rules and norms. "Interconnectedness" is a metric of the number of links between networks within the social unit. "Organizational slack" is the degree of availability of resources for an organization; external characteristics refers to the openness of an organization towards change.

Considering that the TOE framework was developed specifically to describe the adoption of IT at an industry level, this model will be used as part of the theoretical framework for the thesis in

combination with the DOI model. Both of these models were developed to be used at an industry level; the DOI framework emphasizes the importance of institutional awareness, and the TOE framework includes the environmental context of technological adoption. The combination of both models was a valuable and useful tool for structuring the questionnaires and the interviews, as both models produce a solid baseline for explaining the phenomenon of technology adoption within a firm.

2.3 Relevance of models for proposed research.

The TOE framework and the DOI model provide an accurate understanding of how the diffusion and adoption of innovation works across industries. By using the constructs related to each model it becomes easier to bridge the gap between the theory in the model to the way the research will be conducted. For example, special constructs in the TOE framework, such organizational and environmental factors that affect the adoption of technologies, can be considered when selecting and the designing the structure of the questions for the interviews.

Using the aforementioned models can also be helpful for uncovering other factors that help in explaining and predicting the adoption of the technology. Zhu, (2005) found that competence, firm size, financial commitment, regulatory support, and competitive pressure are critical factors within the TOE framework (Zhu, 2005). Kuan, (2001) confirmed the validity of using the TOE framework in technological adoption at an industry level, using six determinants to describe the process of adoption: technical competence, industry pressure, cost structure, government pressure, perceived usefulness, and, finally, indirect perceived usefulness (Kuan, 2001).

2.4 Research framework and hypotheses.

To gain a deeper view of the factors that shape and influence the adoption of Industry 4.0 Technologies revolving around Cyber Physical Systems among the shipbuilding Industry, this study adopts the TOE framework stablished by Tornatzky (Tornatzky, 1990). Other models were studied during the research process such as the Technology Acceptance Model (TAM) developed by Davis (Davis, 1986), and the Diffusion of Innovation Model developed by Rogers (Rogers, 1995); however scholars have concluded that the inclusion of organizational and environmental

factors can eventually facilitate or inhibit the adoption of the technology across the firm. Also, researchers such as Chau, (1997), suggest that the TOE framework developed by Tornatzky (Tornatzky, 1990) allows the assessment, at different levels, of how different aspects could eventually affect the adoption of an IT related technology. Therefore, the framework provides a useful guide for investigations into the factors that influence the adoption of innovation; this agrees with what Chau (1997) mentions: specifically, that the decision to adopt innovation within a firm is not only about the technology but also about surrounding factors such as the environment and the organization.

As a consequence, the TOE provides a complete foundation for exploring the adoption of technology, but can also be valuable for assessing pre and post adoption research. Researchers such as Ismail, (2016) found the model useful for the assessment of the initial stage of adoption of a technology wherein the user makes the commitment to accept or to reject new technology Ismail also states that the implications of TOE in a post-adoption stage regards the decision of the user to continue the use of the technology or to discontinue its use (Ismail, 2016).

In the previous chapter special constructs were established during an extensive literature review regarding factors affecting the adoption of Industry 4.0. These constructs are assumed to apply in a general manufacturing setting. Researchers such as Eze and Chau , demonstrated the importance of using the TOE framework for identifying innovation characteristics, where consideration of the external environment and organizational structure was quite useful in explaining the process of adoption a new technology in a firm (Eze, 2013) (Chau, 1997) (Awa, 2016).

2.4.1 Technology.

In the TOE framework the context of technology refers to the innovation that is planned for implementation in the organization (Ismail, 2016). Therefore, it is related to the technologies available to the organization which can be successfully implemented in order to improve different processes in the industry, and, as such, its principal focus is in how the technology, *by its own characteristics*, can affect the adoption of innovation.

Technological factors in this study align with theory of perceived behavior; where users' agility is shaped by the availability of resources to exploit the complete potential of the available technologies and innovations (Awa, 2016). Scholars such as Zhu and Kramer emphasize the importance of external and internal technology resources, such as ICT infrastructure and ICT technical know-how, and also other factors like technological reliability, cost, quality, and the evaluation of the total benefits of the technology, influence the processes of adoption of the technology (Zhu, 2002)(Kramer, 2002). However, researchers such as Chau demonstrated the importance in combining the TOE framework with the Diffusion of Innovation model developed by Rogers as it incorporates critical characteristics that influence the adoption of the technology such as: compatibility, complexity, observability, relative advantage, and trialablility (Chau, 1997) (Rogers, 1995) (Ismail, 2016)., Because the purpose of this study is to identify key factors that influence the adoption of technology in an organization trialability and observability will not be incorporated in the model; it is, therefore, consistent with the ten factors identified by Tornatzky important in the adoption of a technology. They did demonstrate, however, that only three had a significant effect in the decision process of adopting a technology: compatibility, relative advantage and complexity (Tornatzky, 1990) (Ismail, 2016).

Resistance to change has also been shown as a normal reaction and a barrier to introducing a new technology in a firm, perceived compatibility and perceived values are also important predictors in the process of adoption of a new technology (Awa, 2016). Also, Lee found that innovation that is correlated with operational values has a better chance to be adopted than other technologies (Lee, 2004)(Awa, 2016). IT infrastructure provides the necessary platforms upon with industry share content in real time, meaning that the increase of the Industry 4.0 adoption rate within an organization will increase in an incremental way as the IT infrastructure is improved. Companies tend to perceive the costly process of implementation as a drawback, especially if sub-par infrastructure increases the cost .The know-how of a technology is perceived as the usefulness of the technology, however communication in a digital environment demands considerations beyond the confines of surface perception of usefulness because privacy in data transfer and

security are also essential issues (Awa, 2016). Security, as defined by Hua, is the ability to protect the companies and consumer information the data transaction during transmission (Hua, 2009). After reviewing prior studies in the field of technological adoption six core constructs within the concept of technology characteristics were selected for this study; these include: installed infrastructure, previous knowledge, competencies, cost, relative advantage, compatibility, and complexity.

2.4.2 Organization.

The factors related to the organization are descriptive by nature and are related to the availability of resources; they concern the internal processes of an organization, especially those factors that either hinder, or facilitate, the adoption and implementation of innovation (Chau, 2014)(Awa, 2016).

Through literature research other factors were identified that affect the adoption of innovation relating to the organization such as: top management, available expertise, type of product, corporate and ownership culture, as well as conditions facilitating the adoption of a technology like: available information sources and communication channels (Awa, 2016). Other practical reasons cited by companies adopting a new technology were identified by Ismail, (2016) through literature research identifying factors that affect adoption of new technologies such as financial readiness, organizational culture, and IT experience for instance, were considered important factors behind a companies' decisions to commit to the process of adopting a new technology (Ismail, 2016).

2.4.3 Environment.

The environmental context considers the general area where the firm organizes its business (Tornatzky, 1990). In other words it views the surroundings of the organization, evaluating how external factors influence the motivation to adopt a technology across a firm (Ismail, 2016). Tornatzky also reported other factors that shape environmental factors such as: competitive pressure, government policies, existing trading partners, and strategic alliances (Tornatzky, 1990). Based upon evaluation of these factors, adoption of Industry 4.0 technologies can be the

consequence of external pressure exerted on the firm's environment (Chau, 2014). Porter and Millar (1985), suggest competitive pressure plays a role of significant importance in the adoption of innovation, and also suggest that using modern technologies changes the competitive game, restructuring the industry and thereby helping to outperform rivals. Government policies also can have an effect in the process of adoption of a new technology depending if the policy boosts or hinders innovation (Alatawi, 2012)

After reviewing prior studies in the field of environmental factors with positive or negative effects upon the adoption of a technology, three core constructs were selected: Competitive pressure, government policies and external support.

2.5 Chapter Conclusion.

This thesis aims to find the possible challenges and success factors of implementing's Industry 4.0 technologies in the shipbuilding industry. The application of theoretical models such as the TOE Framework (Tornatzky, 1990), and DOI (Davis, 1986), offers valuable insights that are useful in explaining the end user adoption at an Industry or Organization level. Consequently, specific constructs from each of the involved levels in the framework will be used as background knowledge to underpin the special aspects that should be considered when studying the adoption of a technology within an industry. After the constructs were clearly defined they were used to develop the main questions for the interviews used to obtain the empirical data for the present thesis using a explorative qualitative research approach that will be further explained in *Chapter 4.*

3.Theory and Literature

After having described the research design in the previous chapter, this chapter describes previous research done in the field of Industry 4.0 technological adoption across industries, as well as defining the research gaps found in literature. First, it is necessary to define the technologies involved in Industry 4.0, and study the possible impact in the shipbuilding industry while also providing a background at a general level. This background helped later on during the research by aiding the fulfilment of the research objective and satisfactorily answering the main research question. Second, positive and negative aspects of technology implementation were considered to analyze the connection between the Industry 4.0 technologies and the shipbuilding industry.

3.1 Literature Review.

The literature used for the review was found using a systematic literature research approach. The review started by looking for existing literature in the area of Industry 4.0 acceptance in general manufacturing in order to establish a baseline of the general academic contributions made in this area. The literature search was bounded between the year 2012, when the concept of Industry 4.0 was introduced, to 2018. The information was found using a systematic key word search, on search engines including the TU Delft repository, and Google Scholar using the following terms: "Industry 4.0 in manufacturing," "Internet of Things," "cyber physical web," and "Shipbuilding." Much of the most useful literature research came from the following documents:

Table 3: Industry 4.0 Literature Research.

	Name	***Content***	***Author***
1	Mckinsey report	Industry 4.0 study	(Mckinsey, 2015)
2	Deloitte report	Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies.	(Deloitte, 2016)
3	Industry 4.0: Securing the Future for German Manufacturing Companies	Challenges implementing Digitization in manufacturing	(Balasingham, 2016)
4	What is Industry 4.0	Working definition of Industry 4.0	Federal Ministry of Education and Research (2016).
5	DBR (2014). Industry 4.0	Upgrade of Industry Standards in manufacturing	
6	Change in manufacturing landscape	How virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective.	(M Brettel, 2014)

3.2 Background of Industry 4.0.

In the late eighteen century, an important transition took place from rural societies working in agriculture in Europe towards a society that revolved around industry. This change was, in part, initiated by the introduction of disruptive technologies such as steam engines, which became a source of mechanical production across multiple industries (Khan, 2016). The development of the steam engine played an important role in the development of the textile and iron industries, which profoundly influenced the Industrial Revolution. Also, other industries were positively affected by the introduction of steam engines such as the communication and transportation industry, which helped to improve the scale and scope of overall production (Balasingham, 2016).

The second grand industrial revolution started at the opening of the twentieth century with the introduction of electricity replacing coal and oil as a primary source of energy. This resulted in increased development in manufacturing processes, for instance, the introduction of the assembly line (Wolter, 2016). The economic gains facilitated by these new production processes started result in the development of an established middle class of workers. The third industrial revolution, also known as the digital revolution, started in 1970 and is considered to be still ongoing today(Deloitte, 2015). During this revolution, computers played an important role in the transition from an industrialized society to information of networks. The introduction of digital and electronic systems allowed the development of automation within industrial processes. Also, the introduction of computers allowed the development of areas such as biotechnology and microelectronics; opening the door of new production processes and methods, which generally had a positive impact in the final development of products, thereby increasing the benefits transferred to the consumer (Wolter, 2016). Figure 4, below, illustrates the history of the development of the Industrial Revolution (Research center for intelligence, 2014).

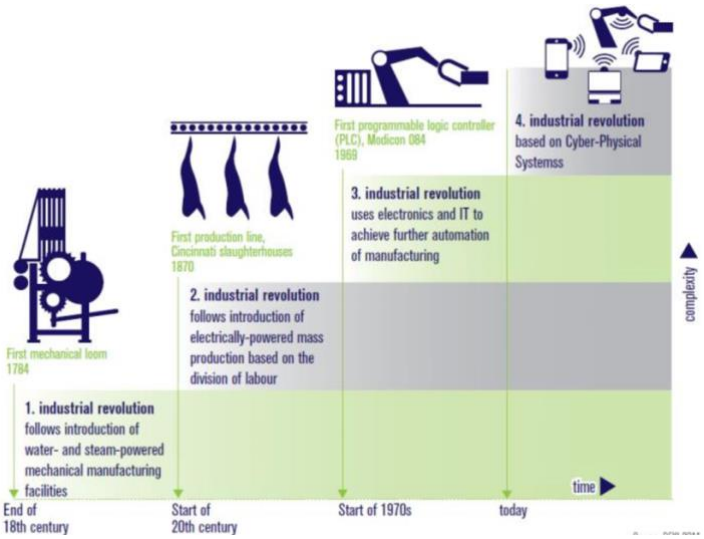

Figure 4: The development of Industrial revolutions. (Research center for intelligence, 2014).

To compete with rising new economies such as India and China, and, moreover, to add value to the product, developed countries started to introduce advanced technologies aimed at increasing production efficiency. In Germany and in the U.S.A. such initiatives were named the fourth industrial revolution (Venkatesch, 2003). In Germany, the revolution was driven by the government and is referred to as Industry 4.0. Khan, (2016) defines Industry 4.0 as a revolution that is enabled by the incorporation of advanced technologies at the production level, bringing new value for both customers and for the organization (Khan, 2016).

3.3 Defining Industry 4.0 and its characteristics.

According to several scholars, there isn't a strict definition of Industry 4.0 nor a clear interpretation (DBR, 2014). In 2016, the Department of Education and Research of Germany defined Industry 4.0 thus:

"Industry 4.0 combines production methods with state-of-the-art information and communication technologies. The driving force following this development is the rapid increasing digitization of the economy and also the society. The technological foundation is provided by intelligent and digital network systems that will make largely self-managing production processes possible."

Similarly, Brettel, (2014) gives the following definition: *"Industry 4.0 focuses on the establishment of intelligent products and production processes"* (Brettel et al., 2014). Other experts of Industry 4.0 have addressed the change in the industry as part of a process of evolution, using definitions like:

"Industry 4.0 is the technical integration of (CPS) in production and logistics as well as the application of the Internet and its services for industrial processes. The resulting consequences also have an affected the value chain, and business models, the downstream services and the work in progress" (Wolter et al., 2015)

Recently, a study conducted by Deloitte, (2015) an advisory company produced a simple definition of Industry 4.0: defining it as the union between the real and the virtual world giving birth to Cyber-Physical Systems. Also, Mckinsey (2015) defines Industry 4.0 as:

"The next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business intelligence capabilities; new forms of human-machine communication such as tactility interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing." (Mckinsey, 2015).

A general summary of the various definitions mentioned above was deemed useful, and, ultimately, served as a guideline for the following chapters. This basic conclusion was that all sources mentioned the introduction of Cyber-Physical Systems into industrial applications. The Cyber-Physical System is formed by sensors, objects and actuators that can continuously communicate through the Internet of Things thereby creating a network of machines and products throughout the value chain, enabling the collection of massive amounts of data, accessing and analyzing the data in real time. The Internet of Things also allows sharing information in real time, creating a network between different factories, people, and machines, thereby supporting the

manufacturing and building process by helping to fulfil the dynamic requirements of production and by improving the overall effectiveness of the manufacturing process. Industry 4.0 encompasses many different technologies, such as the Internet of Things, Radio Frequency Identification, cloud-based manufacturing and product development with the final goal of improving the overall efficiency of a company (Lu, 2017). As Roblek, (2015) describes, there are five significant features of Industry 4.0: digitization, automation and adaptation, human-machine interaction, and automatic data exchange and interaction (Roblek, 2015). Every element of Industry 4.0 is highly correlated by using internet technologies and the involvement of sophisticated algorithms.

3.4 How does Industry 4.0 create value in the manufacturing process.

According to Deloitte's (2015) research, Industry 4.0 has the potential to make a significant impact in current manufacturing companies. These impacts include: increased competitiveness, increased flexibility, improved quality, cost reduction, and an increased cyber risk (Balasingham, 2016).

3.4.1 Cost Reduction in manufacturing processes.

Cost reduction in Industry 4.0 can be accomplished through the efficient use of resources (Balasingham, 2016). Efficient use of resources not only entails the responsible use of natural resources but also considers the proper use of human capital and material consumed during the manufacturing process. Deloitte, (2015) study emphasizes the importance of the introduction of smart networks, which create an advantage by allowing all raw material to be traced in real time (Deloitte, 2015). Also, every production process and work activity can be monitored in real time, anomalies are registered automatically, such as delayed activities, machine malfunction, or preventive maintenance. As result the production process can be easily monitored, resulting in an efficient control of resources and the reduction of waste (Balasingham, 2016). Industry 4.0 is, therefore, characterized by the efficient use of resources such as raw materials, human capital, and energy consumption (Balasingham, 2016).

The introduction of smart robotics has also made a positive impact in manufacturing process, helping to improve the overall efficiency of manufacturing activities and reducing the overall raw material and energy consumption. However, surveyed research also found that the high cost of the initial investment is sometimes seen as a drawback, especially for companies with a low throughput of production for whom a return on such a large initial investment is quite far away (Deloitte, 2016).

3.4.2 Increased Competitiveness.

Globalization has made a significant impact in the reduction of production cost and the improvement of production processes, nonetheless companies have still been forced to shift their production facilities to low wage countries, by doing so they can diminish the gap between quality and productivity. According to Brettel, (2014) customers are reluctant to pay high prices for improved quality products. Consequently, companies are forced to adopt new production methods that focus on waste reduction such as lean and agile management (Brettel, 2014). Also Deloitte,(2016) mentions that the logical step to improve the production processes is the introduction of digitization and smart technologies, enabling companies to gain real time access and data analysis of the production processes, because diminishing the boundaries between internal entities as autonomous systems exchange may improve the overall value chain of production (Deloitte, 2016) (Cho, 2008). Therefore, the digitized transformation allows companies to optimize their manufacturing steps, by aiding them to maintain a sustained competitive advantage through the introduction of new and improved products, more efficiently. The interaction between machine and products allows the possibility to gather and analyze data across the different production steps, which tends to have a positive impact on the development of high quality products while simultaneously using less resources tend to increase the overall productivity of the company (Brettel, 2014).

3.4.3 Increased flexibility.

According to Balasingham, (2014) increased flexibility can be defined as the *"-capacity of a company to adapt across four different dimensions: range, intention, focus and temporal,"* (Balasingham, 2016). The introduction of digitized processes helps to increase flexibility by

organizing small value-oriented units, while also decreasing the complexity of the production process (Brettel, 2014). Also, digitalization allows flexibility through rapid manufacturing techniques, where products are assembled using 3d technologies which enable designers to modify the product before a model is actually built. Such technologies also allow the voice of the consumer to more directly re-shape the product, therefore helping to reduce the time need for the design and production of a product (Balasingham, 2016). Also, through the use of Cyber Physical Web based systems, the entire production process becomes more efficient because monitoring activities can be achieved automatically, allowing flexible production in real time. This means that failures-feedback helps in process improvement (Brettel, 2014).

3.4.4 Higher quality and efficiency.

According to Deloitte, (2015) the introduction of digitized technologies will also allow the efficient use of resources, a reduction of energy consumption, and also the decrease of raw material employment might be obtained through the use of new marketing forms and distribution channels focusing on e-commerce and Internet of Things (Balasingham, 2016). Autonomous communication between machinery allows the collection of important data that allows a continuous improvement flow of the production process, and the autonomous exchange between machines allows the optimization of scheduling work activities with limited errors (Davis, Industry 4.0: Digitalisation for productivity and growth. European Parliamentary Research Service., 2015). Lastly, the overall quality improvement of the production process is beneficial as long as the reduction in production defects can actually generate net savings to the company. (Davis, 2015)

3.4.5 Increased Cyber risk.

Cyber risk is triggered through the use of online networks, the internet, and by sharing information. Specific forms of risks appear in the form of hackers, computer viruses, and cyber extortion (Balasingham, 2016). Industry 4.0 is highly dependent upon interconnected networks, where data is continuously shared and analyzed. Consequently, there is a risk that sensitive information can be stolen from companies and used by competitors to imitate products or improve their own merchandise. Thus far, many multinational companies still suffer the effects of cyberattacks even though efforts to protecting the systems have increased (Balasingham, 2016).

3.5 Factors positively affecting the adoption of Industry 4.0.

The initial phase of the research framework is to understand, through the use of literature research, the principal factors that positively or negatively affect the adoption of Industry 4.0 technologies in manufacturing. Therefore, this section will gather critical factors in the adoption found in literature. According to Deloitte and Balasingham, there two principal factors that may have a positive influence in the adoption on Industry 4.0 technologies in manufacturing: firstly , firm size, and, second, Information Technology (IT) infrastructure (Deloitte, 2016) (Balasingham, 2016).

3.5.1 IT infrastructure

Existing installed infrastructure is crucial in the process of incorporating Industry 4.0 manufacturing strategies. Deloitte, (2016) also mentioned that, as new companies adopt smart networks and digital technologies, these networks are crucial in the foundation of Cyber Physical Systems (C.P.S) that will require the improvement of general IT infrastructure and connectivity (Kagermann, 2014). This process is characterized by a need for high bandwidth and high network speeds for data intensive applications to guarantee quick run times for critical uses (Kagermann, 2014).

Broadband infrastructure should ensure high quality communication, guaranteeing efficient data exchange between smart industries and smart systems. For instance, Kagermann, (2014) mentions the important role of the government in implementing high level standards for IT infrastructure (Kagermann, 2014). PwC, (2014) surveyed 235 manufacturing companies to investigate the relevance of IT infrastructure, finding that the key for a successful adoption of Industry 4.0 technologies is connecting all systems in one network, and establishing a specific importance in the management of the data exchange process within the installed infrastructure, ensuring that exchange of data and analyze of data is done in real time (PwC, 2014).

3.5.2 Firm size effect in the adoption of Industry 4.0 technologies.

The second factor mentioned by Deloitte, (2015) that has a direct effect in the adoption of Industry 4.0 technologies is firm size; the report mentions that large manufacturing firms tend have better

financial capabilities and technical knowledge to initialize transfer to "smart industry" practices (Deloitte, 2015). Furthermore, the report argues that big companies build upon past experience and knowledge which helps them in the transition toward the new Industrial Revolution, particularly by helping them to truly understand the importance of the transformation, while smaller companies may disregard the importance of the transition as they do not have the same experience necessary foresee the direct advantages of upgrade (Deloitte, 2015).

However, some scholars have mentioned the importance of digital transformation and the adoption of Industry 4.0 technologies for small and medium industries. Deloitte, (2015) also mentions that it is easier for smaller companies to incorporate new IT infrastructure, while bigger companies may be reluctant to change their traditional processes, because they tend to have more deeply rooted operational processes. These immobile establishments could make it relatively difficult to implement the new technologies in their manufacturing procedures (Deloitte, 2016).

In addition, Geissbauer, (2014) mentions that the adoption of Industry 4.0 technologies of SME can be a critical success factor allowing smaller corporations to compete with bigger companies; there, the transformation can serve as a source for developing a successful competitive advantage (Geissbauer, 2014). Larger firms may have an advantage on implementing new technologies with respect to the number of available workers, which means companies could more easily start hiring new highly skilled personnel in the area of IT and infrastructure, while, for smaller companies, it would be difficult to change their current work force (Balasingham, 2016).

3.6 Factors Negatively affecting the adoption of Industry 4.0 technologies.

According to Davis, (2015) there are three principal factors that negatively affect the adoption of Industry 4.0 technologies in manufacturing: lack of resources, reluctance to change, and a lack of special skill (Davis, 2015).

3.6.1 Lack of resources.

According to Davis, (2015) the lack of financial resources consists of the difficulties faced by a manufacturing company in financing the initialization cost of the adoption of Industry 4.0 technologies. Driving the upgrade process toward digitized manufacturing represents a very big initial investment (Davis, 2015). Therefore, a large proportion of SMEs fear to make the financial commitment mainly because it is difficult to demonstrate the return of investment over longer periods of time (Davis, 2015). Inversely, multinational corporations, or big firms, might be willing to take the risk, as the financial outlay would be small compared to annual turnover. Bigger companies are also more diversified which means that the cost of investment can be balanced by other sources of income (Davis, 2015) .

3.6.2 Reluctance to change.

Traditional manufacturing processes and business models need to change in order to succeed in the adoption of Industry 4.0 technologies. Changes include the need to build complex networks, which requires business leaders to adopt knowledge from other areas or merge their business processes with other firms (Davis, 2015). Many companies are reluctant to merge or to make new strategic alliances because they are used to traditional ways of manufacturing. This means that adopting a disruptive change is not easy when high levels of uncertainty are present in the investment. The implementation requires the support, not only of top level management, but the whole organization (Balasingham, 2016)

3.6.3 Required skills to implement Industry 4.0 technologies.

The transition towards the successful implementation of Industry 4.0 technologies includes the need for skillful workers in the areas of IT and digital technologies (Davis, 2015). Thus, companies that want to shift towards Industry 4.0 standards need to hire workers skilled in these areas, or retrain current workers (Balasingham, 2016). Davis, (2015) also mentioned the importance of hiring qualified staff to manage digital processes. Industry 4.0 technologies will radically change the tasks and roles of workers. Consequently, training workers in digital platforms is a basic

necessity for companies willing to start the transition towards smart technologies, while at the same time stimulating their personnel development (Kagermann, 2014).

3.7 Difference between the Shipbuilding Industry and process industry.

The shipbuilding industry presents many-layered differences when compared to other process industries. According to a report submitted by Bert Geisler , (2016) during the Hamburg Shipbuilding fair in 2016, the use of specific computer technical support has increased this difference, mainly because the use of 2D drawings creates difficulties during the integration between circuit diagrams and logic plans. For this reason, interdisciplinary cooperation between the different design stages is not used as value chain advantage, also the development of the product, production planning and production operation is developed in a sequential manner where parallelization of this process are still underdeveloped. Nowadays, modern shipyards should be able to cope with parallelization of methods. As an example, the construction of the hull and structure may be finished before the main engines of the ship have arrived, this means that all the primary connections of the motor, such as electrical cabling and plumbing must be considered in the hull/structure design beforehand; this difficulty extends to most of the components of the ship including main and auxiliary machinery. The complexity of the shipbuilding process hinges on the fact that everything must be planned and tested before it can be installed; all with the shipbuilding industry still depending on 2D drawings. (Geisler, 2016)

3.7.1 Background of Industry 4.0 in Shipbuilding.

Since the early successes of lean production systems in the early 70´s, there have been several large disruptive trends in manufacturing including: the outsourcing of manufacturing in the 90´s, and the automation phenomenon that also started to take place in earnest in the 90´s. The fourth significant disruption in production is Industry 4.0. This revolution can be seen as the next phase of digitization of the manufacturing sector, driven by several emerging technologies, namely: the massive use of sensors and the coincident rise in data volume. The subsequent emergence of data analytics that has increased the complexity of human-machine interaction, helping to transfer the digital system into the physical world with developments such as Internet of Things and Cyber-

Physical Systems. Most of these technologies are already in a mature phase and have been implemented across several industries with high reliability and cost-effectiveness and are therefore starting to be appealing to the shipbuilding industry. (Brettel, 2014)

According to the *Global Industry 4.0 Survey*, annual investment in the digital sector are expected to surpass US 907 billion per year through 2020. Such investment is expected lead to additional revenues of US 421 bn annually. The scope of Industry 4.0 in other manufacturing applications can be directly transferred to shipbuilding. For instance the use of Cyber-Physical Systems started the use of "Smart Factories," the use of CPS could also start the trend of "Smart Shipyards." (CGI GROUP INC, 2017)

3.8 Challenges For implementing Industry 4.0 technologies in shipyards.

To further understand the difficulties and the challenges of implementing Industry 4.0 technology in shipyards that build unique products, the problems will be grouped into three different sections*:* availability of process and product information, product complexity, and low throughput.

3.8.1 Availability of product and process information:

The design of a ship is a complicated process and its well modeled by the design spiral concept shown in in (figure 5). The initial part of the process starts off with a very general concept of the type of ship that is required; this requirement is received from the customer. Next, general measures and principal functional characteristics are determined, and the process continues. As soon as every cycle is completed, modifications can be applied to prior cycles. For instance, in calculating the required power to achieve a particular speed, you may find out that you require a bigger engine; in this specific case you would need to change structural supports to fit this bigger engine. Thus, many iterations are done in order to achieve the preliminary design of the ship. However, a lot of the detailed information will still be missing at the end of this preliminary design phase (Perez, 2015).

In the subsequent manufacturing process, each segment of the vessel is transformed from a 3D model into CNC codes, and the piece is subdivided to fit onto a series of 12X3m metal sheet cutouts. To reduce the lead time the CAM process is overlapped with the manufacturing process, creating a bottleneck if not all the information required for the process is available. Such bottlenecks can produce delays or reprocessing that ultimately affects the final delivery of the product. This type of delay especially affects shipyards that build Unique Product Ships because of the large variability of the designs typically requested in the construction of luxury yachts and military vessels. (Perez, 2016).

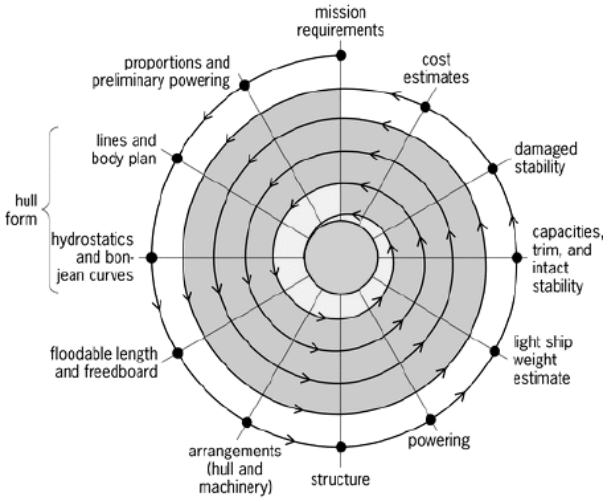

Figure 5: Design spiral in Shipbuilding (Perez,2015)..

3.8.2 Product complexity.

The processes involved in shipbuilding consist of several work stages consisting of the design segment, manufacturing, assembly of prefabricated blocks, pre-erection, and quay. In the design stage, the ship is divided into several blocks. Each block is produced and designed with specific characteristics that fit to its unique structure and functionality. Consequently, the blocks are aggregated into the primary structure of the ship (Park, 2014). The number of blocks used to build a ship differs significantly; a large container ship usually needs up to 250, while a super luxury yacht can be produced with 35 to 55 blocks (Cho, 2008). Therefore, the block-building process is crucial; it involves more than half of the total building process. Thus, it is essential for a shipyard to have a reliable and capable scheduling system that accurately estimates the minimum man-hours for each activity that is scheduled (Cho, 2008).

3.8.3 Low throughput.

When compared to other large shipyards, shipyards that build tailored ships have very low throughput. Consequently, the resources available to invest in new technologies and tools are usually limited. As an example, Daewoo Shipyard spent 980,000 USD to develop their scheduling tool; the task was achieved over three years requiring 27 researchers. According to Lee et al, the investment yielded an increase of output 5% (Lee, et al., 1997). Also, the lack of standardization in the processes used by UPS yards makes the decision to implement Industry 4.0 technologies a difficult one, mainly because it is not easy to predict the return over the investment (Detty, et al., 2000).

3.9 Conclusions and implications.

The present chapter presents a series of concepts and theories retrieved from surveys and available information online using a systematic search approach. From this literature review, several common factors that affect the adoption of Industry 4.0 technologies were discovered. In general, research started with concepts developed by Balasingham; this study was used as a gateway to other studies such as that produced by Deloitte and McKinsey & Company on how to navigate digitization of the manufacturing sector, with the following findings (Balasingham, 2016) (Deloitte, 2015) (McKinsey&Company, 2015):

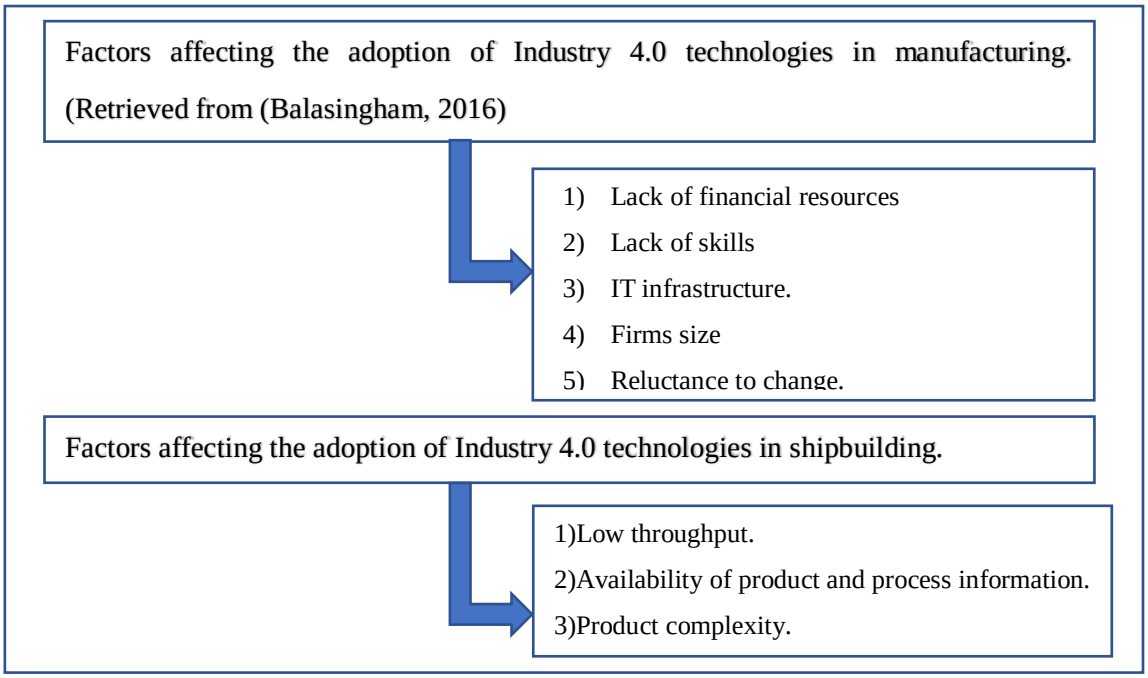

Figure 6: Constructs related to technology adoption in manufacturing

Finally, eight important constructs were identified during literature Review that affect the adoption of Industry 4.0 technologies in the shipbuilding industry. These constructs in conjunction with the TOE framework and the DOI model were used to design the structure of the questions for the interviews.

4.Interview Approach in Detail.

The methodology applied for interview execution is explained in this chapter. The methodology is divided into two core parts. Firstly, on the basis of the overall thesis research questions, a technology acceptance model was selected to assess the important factors that affect the adoption if Industry 4.0 technologies across the Shipbuilding Industry, the chosen model for this task is the TOE Framework (Technology, Organization and Environment) (Tornatzky, 1990). Secondly by combining the chief factors that affect the adoption of Industry 4.0 technology, as derived from the literature review, with the constructs obtained from TOE framework. This model suggests that there is a significant effect on the relationships between technological, organizational and environmental factors that affect the adoption of Industry 4.0 technologies across the shipbuilding industry.

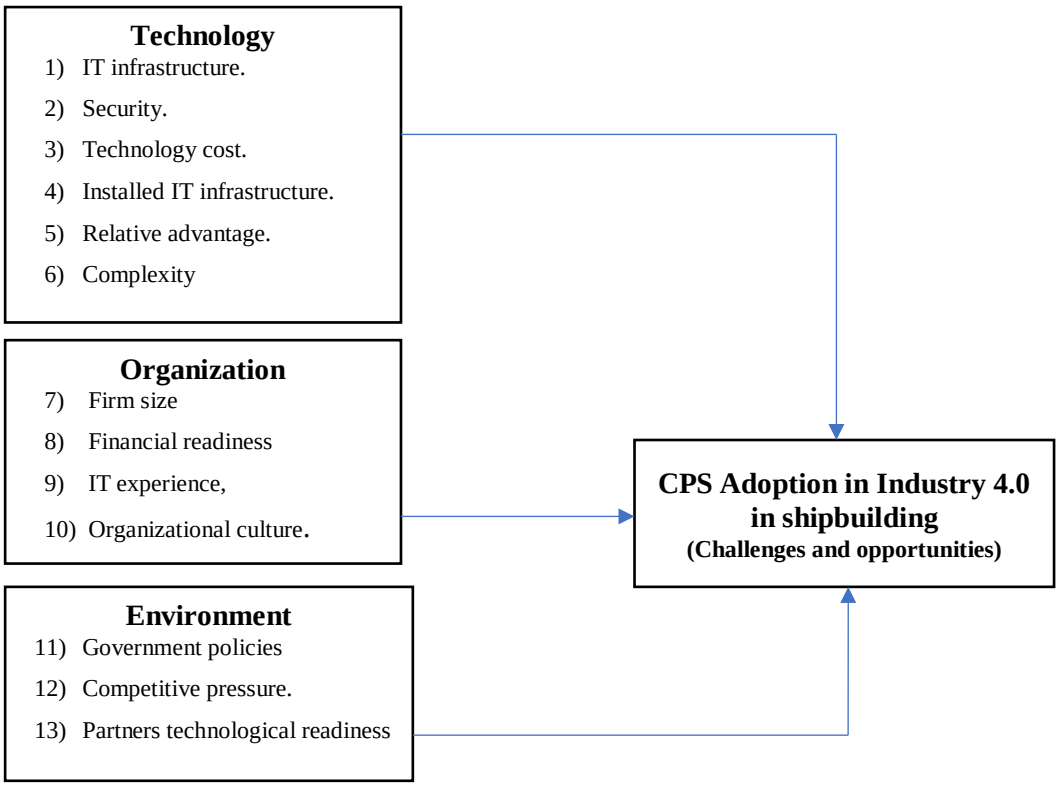

Figure 7: Proposed framework explaining Industry 4.0 technologies in shipbuilding.

4.1 Problem analysis

For the problem analysis, interviews with experts were conducted to gain a more insightful view on the identified issues. Later on, content analysis was used to develop a phenomenological qualitative research approach (Creswell, 2013) in which 22 interviews were conducted with cooperation from experts from three different backgrounds: shipbuilding experts, Industry 4.0 experts, and, finally, developers of technology related to Industry 4.0.

4.2 Expert Interviews.

Experts in Industry 4.0 manufacturing and shipbuilding were interviewed using semi-structured questions. The qualitative data obtained from the research formed pool of information collected from interviews, face to face meetings, and the analysis of the aforementioned underlying theories that revolve around existing Industry 4.0 implementation in the manufacturing sector that could be readily applied to the shipbuilding sector. The collected data was also analyzed, interpreted, and coded to extract key findings that helped to achieve the research objective.

The data was collected during one month in two separate rounds. In both rounds, interviews and face to face meetings were used to obtain the data. The respondent groups were divided into a representative group of experts hailing from three main fields: The shipbuilding sector, Consultancy companies with experience in Industry 4.0, and finally technology developing companies. The primary goal of these interviews, as part of the qualitative research, was to gain a clear picture of the opportunities and challenges of implementing industry 4.0 technologies, and also to gain practical recommendations on how a shipyard could start the transition process towards implementing Industry 4.0 technologies.

Ten experts in Industry 4.0 technologies were selected for the first round. The collected data during this first round helped to redefine and structure the questions used in the second round. Thus, yielding a clearer understanding of the problems and challenges associated with the adoption of technologies related to Industry 4.0. The second round of interviews involved 12 experts in the application of Industry 4.0 technologies to shipbuilding applications. During the second round the

improved questions from the previous round were used. Finally, the answers obtained during the two rounds of interviews were used to gain a better idea about the challenges and opportunities of implementing Industry 4.0 technologies in the shipbuilding industry.

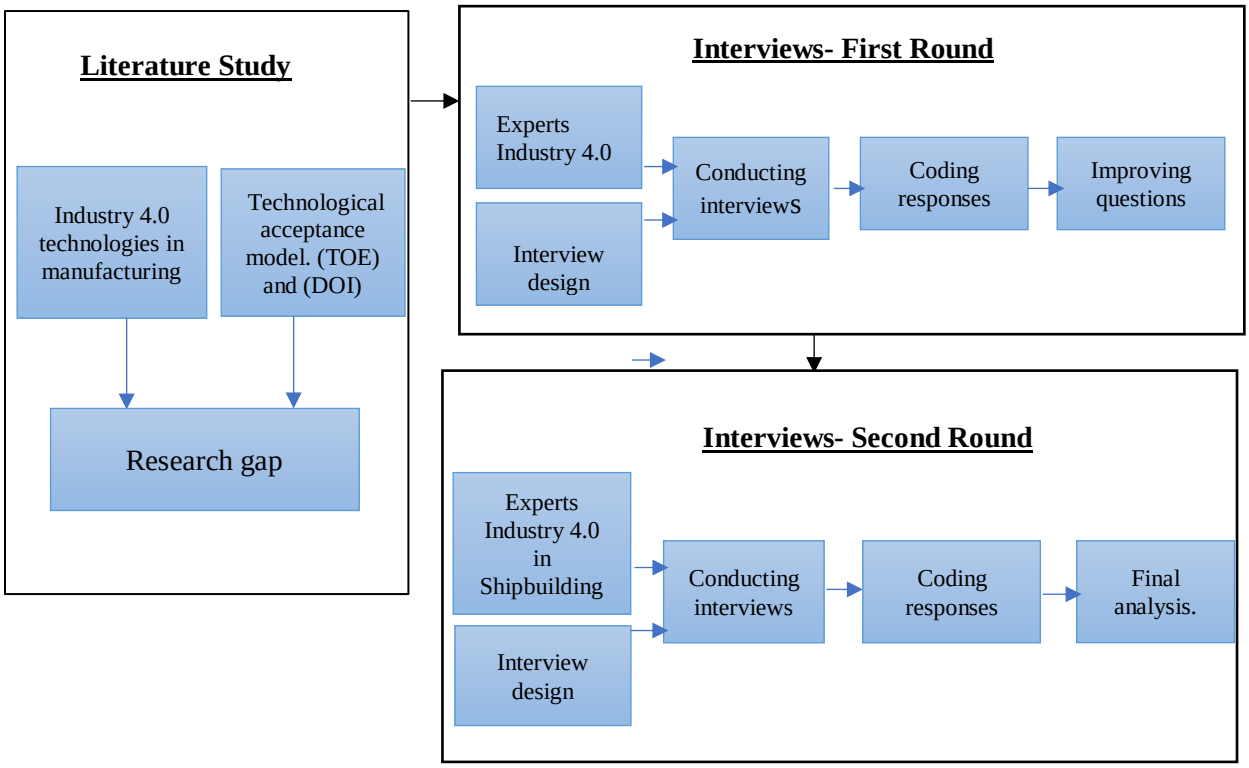

Figure 8: Qualitative research design.

During the research, semi-structured interviews were used. This type of procedure is generally used to collect attitudes, facts, and opinions about a specific topic (Wilson, 2014). To gain deeper insight into the topic, the first questions were structured according to the level and area of expertise of the interviewee. Further questions were then asked to encourage new ideas that were not included in the first segment of the interview. At the beginning of the questions, a clear framing and an explanation of the purpose of the research was made to attempt to avoid biased answers and deviations from the topic in question. Also, during the interview, sub-queries were used to clarify each answer, and also to gain more in-depth knowledge about a specific question. Finally, the interviewer had discretion to decide when to end the interview when it became clear that enough information had been obtained about a specific subject (Channel & Kahn, 1968).

Consequently, as more interviews were developed, a sequence of similar answers were obtained from the interviewees, eventually reaching a saturation point of the acquired answers. This saturation point was the moment when no more interviews were conducted.

4.3 Interview Process

To gain as much quality information as possible, the interviews were prepared using the following 8 step procedure developed by Bailey. The steps are helpful to enhance the quality and the validity of the interviews (Bailey, 2008).

Figure 9: Interview process. ***(Bailey, 2008)***

The first part of the process starts by specifying which information is required. This first step is accomplished by expanding upon the primary research questions and the research objective. In the second step in the process, questions are developed based on two guiding concepts: the theory collected in the initial literature review on Industry 4.0 adoption, and the TOE Framework (Technology, Organization and environment). Particular constructs from the theory were used to develop the questions (See chapter 3). In the third and fourth steps, the correct candidates are chosen for the interviews. This was achieved using a convenience sampling method: namely, by searching on LinkedIn for specific profiles based on experience and knowledge in Industry 4.0 technologies and the Shipbuilding Industry. Almost 50% of the interviews were done face to face, travelling to different parts of the Netherlands such as Amsterdam, Rotterdam, Den Haag, and Dordrecht. The rest of the interviews were done using Skype and WhatsApp calls. All of the

interviews were recorded with previous permission from the interviewee. After the interview was finished, and accurately recorded, the interview was transcribed, then the transcript was sent back to the interviewee to allow them to check, and ultimately accept, the responses. Finally, if the response were approved, the information was processed using coding and Content Analysis. The knowledge obtained from the Content Analysis was used to derive a conclusion on the central research questions and the research objective.

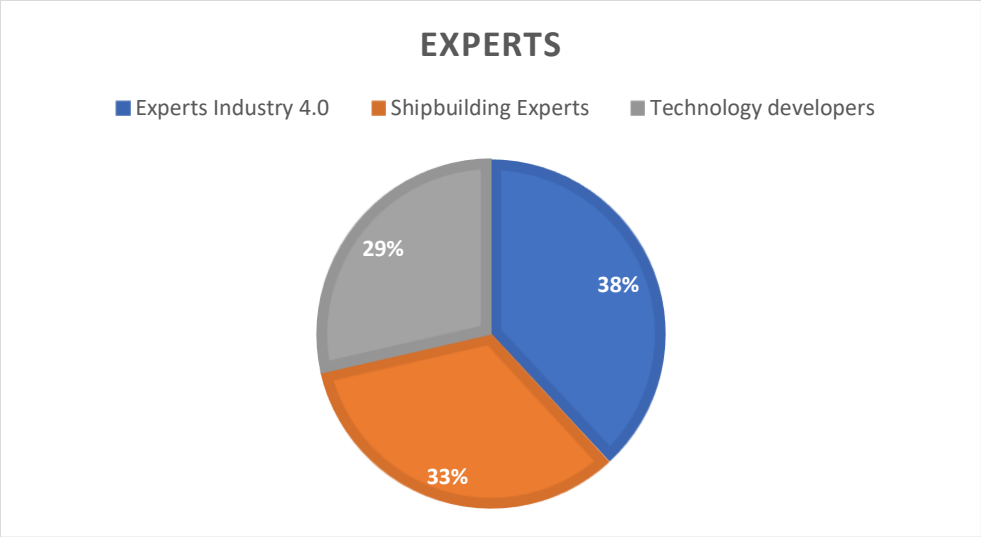

Figure 10: Distribution of experts interviewed from each of the categories.

Questions used during the interviews derived from the TOE Framework:

Technology.

1. What factors of production can be impacted when implementing industry 4.0 technologies?
2. How can the data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?
3. What main obstacles can a company encounter when initiating transformation processes towards digitization?
4. What type of Industry 4.0 technologies would you recommend a company to invest in first when starting the transformation process?

Organization

5. How best to address the problem of lack of relevant IT experience in the process of transformation towards digitalization?

6. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

Environment

7. How do government polices affect the adoption of Industry 4.0 technologies?

8. How can strategic alliances help the transformation process towards digitalization?

9) What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

10) What other factors do you think play an important role in the adoption of Industry 4.0 technologies in a manufacturing setting?

4.4 Transcribing the Interviews

According to Bailey, (2008) transcribing interviews is seen as a straightforward procedure that can often be time-consuming though it sets the basis for the data interpretation process. Gibbs (2007), describes the Golden Rules of transcribing: "*write early and write often,*"and "*don't get it right, get it written.*" (Adapted from Spruijt, 2015). The transcription should be made as soon as possible after the conclusion of the interview, and the transcripts should be structured in themes. This structuring is accomplished by organizing the most relevant questions, and thereby avoiding redundant answers. To transform audio data into text it is necessary to first establish the level of detail required. Based upon this detail level, transcription can be categorized as either denaturalized or naturalized (Bucholtz, 2000). In a naturalized transcription, every detail of the interview is transformed into text while denaturalized transcription is more subject to interpretation. Therefore, it is important that every written response should be clarified and accepted by the interviewee after the transcript is finished. This is done to avoid incorrect interpretations of the text. A balanced combination of naturalized and denaturalized transcription was used during this research to attempt to avoid bias in the transcripts.

4.5 Content Analysis

Content analysis was used to analyze and organize the qualitative data obtained from the interviews. After the data is coded, it can be further analyzed quantitatively. the coding process is a rigorous, step by step, method (Sekaran, 2007). The coding scheme is organized into categories

where different codes are assigned to each of the chunks of the text (Berhard, 2010). For this research, each response of the experts was coded, giving a deep insight in the Challenges and Opportunities of applying industry 4.0 technologies in the Shipbuilding sector.

4.5.1 Description of the process of content analysis.

The encoding scheme is composed of six main steps derived from Bernard & Ryan (2010):

1. Assigning structural codes to each interview.
2. Read the transcript and create an understanding of the context.
3. Analyze the transcript and identify the main problems and issues.
4. Assign theme codes to identified issues.
5. Compose the encoding scheme.
6. Check for consistency.

Each of the expert interviews will get a code from letter A-Z, and every expert was divided in three main focus groups, shipbuilding experts, Industry 4.0 experts and technology developers, the three focus groups were assigned codes (1,2,3). From the shipbuilding experts, a deep insight was extracted regarding the problems and challenges of implementing Industry 4.0 challenges. Industry 4.0 experts contributed insights into essential aspects regarding the implementation of the technologies, the challenges, and also the benefits of implementing these technologies in a manufacturing environment. The answers of each of the focus groups could be very different for some questions, while on others they agreed. Such contrast offers a clear understanding of the issue.

After each respondent was assigned to a focus group (1,2,3), every transcript was read carefully to avoid misinterpretation of the facts. Each of the interview analyses was conducted to avoid context interpretation as much as possible; this helped to yield a comprehensive and unbiased response. Next, the identified responses were marked and listed. Each of the responses received a code relating to its category. Three principal categories were distinguished: Technological (TECH), Organization (ORG) and Environmental (ENV). These categories were obtained from the TOE framework (Technology, Organization and Environment) developed by

(Tornatzky, 1990). Finally, to improve the scheme, the coding was verified for consistency. This was done by crosschecking if similar responses existed between each of the categories, this helped to simplify the process of analysis. In the next chapter an analysis of the results will be presented with a clear explanation on how each code was obtained from the interviews using content.

5. General Results:

The results of the interviews from 22 experts in the fields of Industry 4.0 and shipbuilding industry are presented in this chapter. The main challenges of implementing Industry 4.0 technologies in the shipbuilding industry, according to these experts, were identified, and, by using the method of content analysis, the main issues were presented in an encoding scheme. The total scheme consists of 12 main findings divided into seven challenges and five success factors that arise while implementing Industry 4.0 technologies in shipbuilding. The responses were organized into three principal categories. The first categories of the issues found were the Technology category (TECH), the second issue will be the organization category (ORG) and the last category will be the Environment (ENV).

5.1 Results from the encoding scheme.

A comprehensive overview of the results obtained from the encoding scheme of the respondents is presented in Table 7, and they are marked with the codes (TECH, ORG and ENV). The scheme presents an overview of the obtained repetitive responses from each of the interviewees that reached saturation level. Within Technology (TECH), five findings were distinguished. Within Organization Issues (ORG), four findings were distinguished, and finally, in Environment (ENV), two findings were identified.

In the following descriptions of each of the obtained findings, the coding rules are first explained, illustrating the way the results were derived from the interviews using a rigorous procedure. After this brief description, a quote from each of the experts is included to serve as an example of how the arguments were derived from each of the recorded interviews.

Table 4: General results from the Encoding scheme.

Category	*Subject*	*Code*
Technology (TECH)	Start collecting data from production process	TECH1
	Don't think about the technology first, think about the process.	TECH2
	Shipbuilding depends on craftsmanship, building unique and one of a kind ships.	TECH3
	Think about technology that enhances human performance, not technology meant to replace it.	TECH4
	Start with small projects to have fast success then move to bigger projects.	TECH5
	Understanding cyber risks is necessary.	TECH6
Organization . (ORG)	Top management support is necessary for stablishing any change.	ORG1
	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	ORG2
	The structure and the rigidity of the company affects the adoption of Industry 4.0 technologies.	ORG3
	Shipyards have old fashioned ways of working.	ORG4
Environment (ENV)	Shipyards need to search for companies that have experience in implementing Industry 4.0 and make strategic alliances.	ENV1
	There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	ENV2

5.2 Technology findings (TECH).

All findings related to the challenges of implementing industry 4.0 technologies in shipyards were assigned to TECH, also in this category were aspects such as "strategies to implement technologies successfully." Within this category, five general findings became evident:

- Start collecting data from production process (TECH1),
- Don't think about the technology first, think about the process. (TECH2),
- Shipbuilding depends on craftsmanship, building unique and one of a kind ships. (TECH3),
- Think about technology that enhances human performance, not replace them. (TECH4),
- Start with small projects to have fast success then move to more significant projects. (TECH5).

5.2.1 Start collecting data from the production process (TECH1)

Findings were assigned to **TECH1** when the topic was related to how companies should start the process of implementing Industry 4.0 technologies. Experts mentioned the fact that when beginning the transformation process, companies do not know how to collect the data accurately, or, in other cases, many companies already collect the data but they do not have any way to analyze this information using solutions such as Big Data Analytics. Also, interviewees highlighted the fact that many companies fail at the beginning because not knowing what to do with the information creates deadlock.

Expert Quote:

"Companies should start collecting vast amounts of data if they want to adopt industry 4.0 technologies".

J Spee.

5.2.2 Don't think about the technology first, think about the process. (TECH2)

Issues were assigned to **TECH2** when respondents addressed the fact that companies should not focus only on the technologies they wish to implement, but also should focus on how to model their current situation so they know exactly what area of production they can improve.

Expert Quote:

"Companies should analyze their current problems, understanding where they have more waste, after they are clear, companies can start making small improvements in the company to solve the problems".

R Rouzbeh

5.2.3 Shipbuilding is a lot about craftsmanship and building unique, one-of-a-kind ships. (TECH3).

Findings were assigned to **TECH3** when respondents made points that were specifically related to the difficulty of implementing Industry 4.0 technologies related directly to the manufacturing

process such as: craftsmanship dependence, uniqueness of the products, and shipyards not having a steady line of production.

Expert Quote:

> *"Building a ship is a complicated process as there a lot of moving parts, involving manual labor and craftsmanship of the worker, which means it is sometimes difficult to change this way of work."*
>
> *M Roelhofs.*

5.2.4 Think about technology that enhances human performance, not tech that replaces it. (TECH4)

In many situations, respondents addressed the fact that companies should focus on Industry 4.0 technologies that help people to perform better and be more effective in their work. These types of technologies help humans to perform better, for instance by reducing exposure to situations or environmental irritants that can cause lesions, such as manually moving heavy objects and overexposure to heat and toxins. Issues that mention the fact that companies wishing to start the transformation process towards digitization should focus on technologies that enhance and improve the overall condition of workers were assigned to the category **TECH4.**

Expert Quote:

> *"Industry 4.0 is not about automation on a line of production but using technologies that help the workers to be more efficient in their job."*
>
> *J.L Inoges.*

5.2.5 Start with small projects to have fast success then move to more significant projects. (TECH5)

Findings were assigned to **TECH5** when respondents suggested that shipyards wanting to start the process of incorporating Industry 4.0 technologies should initially focus on developing small projects that demonstrate success in the short term. Respondents also mentioned the fact that demonstrating success and proving a concept in a short time can often help to gain support from top management to develop other projects related to Industry 4.0.

Expert Quote:

"A company should look at cases that can prove an early success, this way you can show people that are actually against change that the technology helps to improve the process."

J Pruyn.

5.3 Organization findings (ORG).

All findings related to organization and management of the companies are listed within this category. In this category a total of four findings were distinguished;

- Top management support is necessary for stablishing any change **(ORG1),**
- Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology **(ORG2),**
- The structure and the rigidity of the company affects the adoption of Industry 4.0 technologies **(ORG3),**
- Shipyards have old- fashioned ways of working **(ORG4).**

5.3.1 Top management support is necessary for establishing any change. (ORG1)

Findings were assigned to **ORG1**, when respondents mentioned the fact that top management support is crucial for the process of adoption of Industry 4.0 technologies. Respondents also referred to the fact that huge investment needs to be made during the adoption process, and without total commitment from senior management, adoption is not possible because the upgrade also requires a significant change in mentality, among other profound changes that would need to occur within the company.

Expert Quote:

"This can only be solved if there is a total top management to make this change in the company, to invest in new technologies and hire new personnel. Changing the culture of people is often difficult because they have a stablished way of doing their work".

H Munza.

5.3.2 Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology. (ORG2)

A topic that was mentioned by almost all the respondents is that companies need to change "*their normal way of doing things*" in order to adopt new technologies. Several factors were mentioned by the respondents concerning how companies should change. Common recommendations were: to create small cross-functional teams, to create new divisions and departments with top management support.

Expert Quote:

> *"The organization of a company does affect the process of adoption of a new technology so small innovation teams should be used, in some cases it's not easy to decide if they are embedded teams or separate units, or if they should function as a business unit. In my experience, they should work as a separate unit but you also have the problem of scaling the operation when the new technology is introduced".*
>
> *J Spee.*

5.3.3 The structure and the rigidity of the company affects the adoption of Industry 4.0 technologies. (ORG3)

Findings were assigned to **ORG3** if respondents addressed the fact that there is a "*relation between the culture of a company and the adoption of the new technologies*". The culture of a company is referring to the structural characteristics of a company: for instance, if it has a pyramidal structure or is organically organized.

Expert Quote:

> *"The culture of a company also has a big influence on how they adapt the technology, because the company needs to influence and modify every single department of the company, if the technology is not accepted in every department and integrated the Industry 4.0 technology will not work".*
>
> *O Heinric.*

5.3.4 Shipyards have old fashioned ways of working. (ORG4).

Findings were assigned to **ORG4** when respondents mentioned the fact that "*Shipyards are attached to old way of doing their work,*" or mentioned different factors such as: difficulties in change because of the mentality of the companies.

Expert Quote:

> *"I have been there and those shipyards really look old fashioned. Labor is really cheap there and the rules are not so strict, that's why shipyards still use these relatively cheap ways of production".*
>
> *M Overbeek.*

5.4 Environment findings (ENV)

All topics related to external aspects of the company's perspective were assigned to the category ENV. In this category two finding were distinguished:

- Shipyards need to search for companies that have experience in implementing Industry 4.0 and make strategic alliances **(ENV1)**
- there is a relation with Government policies with the way companies adopt Industry 4.0 technologies **(ENV2)**

5.4.1 Shipyards need to search for companies that have experience in implementing Industry 4.0 and make strategic alliances. (ENV1)

Findings were assigned to **ENV1** if respondents mentioned the opinion that shipyards or other companies should not go through the process of digital transformation by themselves, or if they mentioned something like: "*shipyards should look for companies that already have experience in the process of adoption of these new technologies*". This categorization also applies to respondent advice that suggested companies go to consultancy companies to help to accomplish their goals.

Expert Quote:

> *"Strategic alliances are very important as shipbuilding companies can gain on the expertise of other companies with similar process where the technology has been proven to work, this can help to make the decision".*

P Huyskins

5.4.2 There is a relation with Government policies and the way companies adopt Industry 4.0 technologies. (ENV2).

Findings were assigned to **ENV2** if respondents mentioned "*that there is a relation between government policies and how companies decide to adopt Industry 4.0 technologies".* The relation could be positive, or, in some cases, respondents also mentioned that there is a negative influence in the process of adopting Industry 4.0 technologies.

Expert Quote:

> *"We would look for any opportunity to apply for grant money to support network development. Look for ways to work with local, state and federal government on implementing".*

B Rout

5.5 Analysis of the Findings.

Content analysis was used to analyze, in depth, the frequency of the responses from each of the interviews, helping to transform initial qualitative data into a more quantitative dataset. This quantitative data helped to gain understanding of how certain findings were more representative than others. The content analysis started with a quantitative representation of the obtained results. Then, using the frequency of the results, an overview of how certain responses stand out from overs became evident. Finally, the chapter ends with conclusion.

5.5.1 Quantification of the obtained responses.

According to the frequency of responses, it became apparent that some categories were more critical than others. This helped to identify factors that were deemed most relevant in the process of adopting of Industry 4.0 technologies in the shipbuilding industry. Also, it is possible that other

aspects could be seen as important when determining the difficulties of implementing these technologies; therefore, each frequency from the obtained categories of the coding scheme were compared and represented graphically. The obtained frequencies helped to define the direction of the most important features of the empirical data.

Table 5: Frequency of findings from each of the expert group.

Findings	***Code***	***Frequency Experts***		
		Shipbuilding experts	***Industry 4.0 experts***	***Technology developers***
Start collecting data from production process	TECH1	3	7	5
Don't think about the technology first, think about the process.	TECH2	2	6	4
Shipbuilding depends on craftsmanship, building unique and one of a kind ships.	TECH3	4	1	1
Think about technology that enhance human performance, not replace them.	TECH4	4	6	4
Start with small projects to have fast success then move to bigger projects.	TECH5	4	5	3
Understanding cyber risk.	TECH6	3	2	3
Top management support is necessary for stablishing any change.	ORG1	5	4	6
Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	ORG2	3	4	4
The structure and the rigidity of the company affects the adoption of Industry 4.0 technologies.	ORG3	4	6	3
Shipyards have old fashioned ways of working.	ORG4	5	2	1
Lack of resources	ORG5	4	2	1
Shipyards need to search for companies that have experience in implementing Industry 4.0 and make strategic alliances.	ENV1	4	4	2
There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	ENV2	2	6	5
Total obtained answers		**49**	**55**	**41**

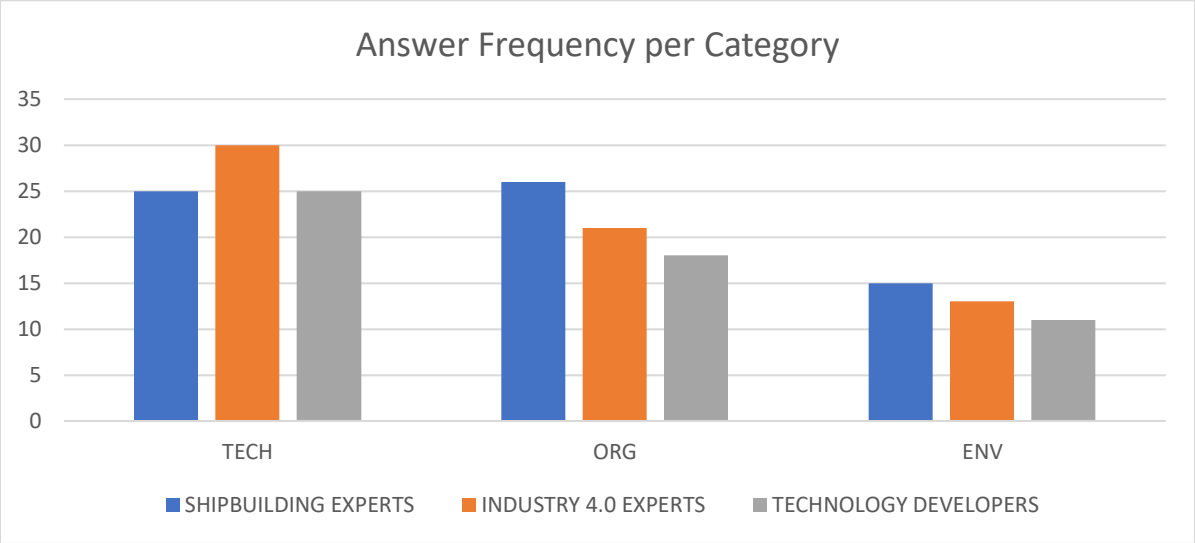

Figure 11: Frequency per category.

5.5.2 Difference between groups.

Several factors appeared to affect the frequencies of the responses, including the numbers of respondents from each group, and also the fact that some experts did not have previous knowledge in the shipbuilding industry. Moreover, some noticeable findings were obtained in several of the questions where most of the experts agreed upon several solutions, recommendations, and the identification of problems in the process of adopting Industry 4.0 technologies. The findings are divided in two main groups: the challenges of implementing Industry 4.0 technologies in shipbuilding, and recommendations to a successful implementation of these technologies. Recommendations such as identifying technologies that enhance and improve human performance and also that companies wishing to initiate in Industry 4.0 technologies should start with small projects to demonstrate early success and then move on to other bigger projects; the findings will be further analyzed in depth in the following chapter developing a clear overview of the problem in issue.

5.6 Conclusions.

The transcripts from the interviews were coded, and twelve main findings were identified from 22 interviews and responses from experts in the fields of Industry 4.0 and also the shipbuilding industry. The main findings were divided in three principal categories, presented in the encoded scheme in (Table 8). The encoding scheme presents an overview of the main challenges and opportunities of implementing Industry 4.0 technology, but also special recommendations were obtained describing ways to successfully implement the new technologies in the shipbuilding industry.

Also, a broad set of challenges and opportunities were identified from the encoding scheme with a really comprehensive overview from each of the categories. Each of the selected categories were rated with differing levels of importance as shown in the encoding response frequency (Figure 11), demonstrating that when assessing the impact and the adoption of a technology, not only the technological factors should be considered, but also factors such as organizational and environmental circumstances are fundamental when establishing relations and drawing conclusions.

EXPLORATIVE RESEARCH:

PART I: Challenges of implementing Industry 4.0 technologies in Shipyards

Figure 12: COTECMAR shipyard.(COTECMAR, 2016)

During the first part of the explorative research, the challenges of implementing Industry 4.0 technologies were analyzed from the encoding scheme, further on in Chapter 7 the success factors towards the implementation of Industry 4.0 technologies will be introduced.

6.Challenges of adopting Industry 4.0 technologies in the Shipbuilding sector.

In this chapter the empirical results obtained from the interviews and that are exclusively with respect to the first part of the main research question are presented. Specifically, the results referring to the challenges of implementing Industry 4.0 technologies are further clarified.

Research Question Recapitulation: *What are the main challenges of implementing Industry 4.0 technologies in the Shipbuilding industry?*

6.1 Main challenges towards implementing Industry 4.0 technologies in Shipbuilding.

According to the findings presented in Chapter 5; a total of seven main challenges were found and are deemed to affect the implementation of Industry 4.0 upgrades in shipbuilding. These results were obtained from the encoding scheme whereby the seven main findings were ranked by the frequency with which they were named by the respondents in each of the categories. These seven represent those categories that reached saturation level. (See *Table 6*). The selected challenges reflect the complexity of the process of adopting Industry 4.0 technologies as perceived by the experts, and also tell about the different interests and opinions possessed by each of the interviewees.

Expert quote:

> *"The challenges that companies face when they start the digital transformation process starts because companies do not understand the concept, and there is not a clear understanding of how the technology can really help the company, sometimes there is much smoke in the environment but nothing concrete, for this reason, companies should focus to understand the concept and how it can really help the company, after this companies should look at the logical steps they should take, helping to know where exactly to go."*
>
> *D Morais.*

Table 6: Obtained challenges from the results.

Category	***Subject***	***Code***
Technology (TECH)	Problems collecting data from production process	**TECH1**
	Shipbuilding depends on craftsmanship, building unique and one of a kind ships.	**TECH3**
	Understanding potential Cyber risk	**TECH6**
Organization. (ORG)	Top management support is necessary for stablishing any change.	**ORG1**
	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	**ORG2**
	Lack of resources	**ORG5**
Environment (ENV)	There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	**ENV2**

6.2 Frequency of the Challenges.

As shown in (*Figure 13*), the **TECH6** category is the factor most often mentioned by experts; the interviewees from each of the three expert categories agreed that Cyber Risk could hinder the process of adopting Industry 4.0 technologies in shipbuilding. The finding **TECH1** is related to the problems shipbuilding companies encounter when beginning to collect new data from the manufacturing process. Also, from (*Figure 13*), it can also be seen that most of the shipbuilding experts mentioned that there are many problems in the process of collecting data in shipbuilding, though this issue was not emphasized as a challenge as much by the other groups of respondents. This can be attributed to the non-shipbuilding respondents' lack of specific knowledge about the unique characteristics of the shipbuilding industry. Experts from these other groups perceived data collecting as a straightforward process in other industries with steady lines of production, diverging considerably from the shipbuilding industry where every ship has appreciable differences from others, as previously explained in Chapter 3.

The same conclusion can be drawn from the **TECH3** category, because the shipbuilding process requires specialized workers with a high degree of craftsmanship through the entire manufacturing value chain. This reliance upon craftsmanship creates difficulties in the adoption of technologies related to Industry 4.0; this is also observable in the variability of the results related to this finding

presented in Figure 11. This situation can also be attributed to a lack of specialized knowledge related to the shipbuilding process.

The findings related to **ORG2** demonstrate consistency among the three groups of respondents, showing that there is an agreement amongst experts on the assertion that highly structured and mechanical organizational schemes can hinder the process of adopting new technologies in shipbuilding, (Later, in Chapter 7, suggestions addressing this challenge are expanded upon). It is also noteworthy that **ORG1** is considered significant mainly by the group of Technology Developers, which reveals a discrepancy with what was found in the literature regarding the importance of the support of top management in the process of adopting new technologies.

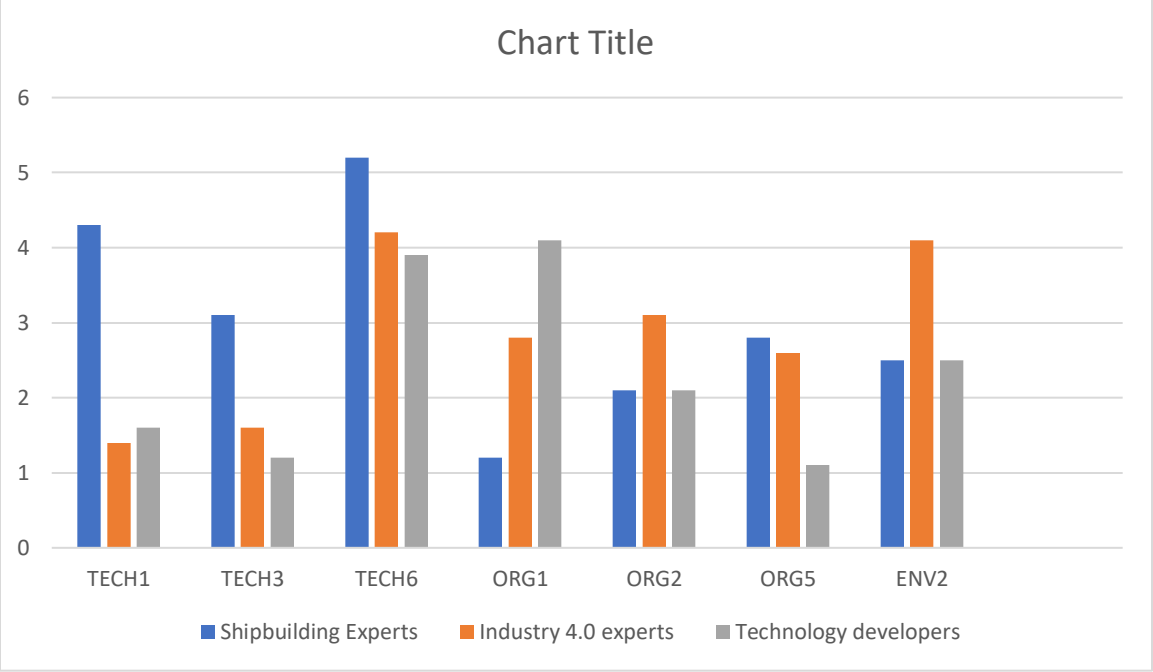

Figure 13: Frequency of obtained challenges among each of the categories.

In relation to **ORG5** findings category, shipbuilding experts and Industry 4.0 experts agreed that a lack of resources is an essential challenge for many shipbuilding companies in the process of adopting technologies related to Industry 4.0, however, the expert group of Technology Developers did not see this factor as relevant in the process of adoption of technologies related to

Industry 4.0. This situation can be attributed to bias, because the Technology Developer respondents work for the companies which would be paid to implement any Industry 4.0 upgrades. **ENV2** also appeared to be important to the Industry 4.0 experts group as shown in (*Figure 13*), which is inconsistent with the associated opinions of shipbuilding experts and technology developers that did not consider **ENV2** as a particularly essential issue in the process of adopting Industry 4.0 technologies. This can be attributed to the fact that interviewees from the Industry 4.0 expert group have more experience and related knowledge regarding the implications of policies and how they affect the process of adopting technologies related to Industry 4.0.

To sum up, the problem issues **TECH1**, **TECH3**, **TECH6**, **ORG1**, **ORG2**, **ORG5** and **ENV2** reflect the main perceived challenges in the implementation of Industry 4.0 technologies in the shipbuilding industry uncovered by this study. It can be argued that the different perspectives and interest from each of the expert groups give valuable insights towards understanding the general problematic towards the implementation of Industry 4.0 technologies. In the next section, each of these highlighted challenges will be furtherly explained in detail with examples of relevant expert quotes.

6.2.1 Technology findings: related to challenges of implementing industry 4.0 in shipbuilding.

Table 7: Challenges related to technology findings.

Technology issues (TECH)	Problems collecting data from production process	**TECH1**
	Shipbuilding depends on craftsmanship, building unique and one of a kind ship.	**TECH3**
	Understanding the potential cyber risk	**TECH6**

As mentioned in Chapter 3, shipbuilding is a very complicated process involving many disciplines and numerous stakeholders, often spread across different geographic locations. It is also a time intensive and expensive process, with macro-level factors pushing each new construction project for shorter times-to-market and also the increasing demand for vessels to be more efficient with the latest technologies . In the following section, the challenges obtained from the **TECH** category

will be explained thoroughly, and specific quotes from each of the expert groups will be given as an example of the acquired responses.

6.2.2 TECH1: Problems collecting data from production.

In (*Figure 13*) it can also be seen that **TECH1** was mainly recognized as an issue from the Shipbuilding group of experts, the remaining group of interviewees did not see this factor as an important challenge towards the implementation of Industry 4.0 technologies in the shipbuilding process. Thus, there was a clear difference of opinions between the shipbuilding experts and the other two groups of experts, where 6 out of 9 respondents from the shipbuilding group mentioned the difficulties in collecting data. The experts mentioned suspicions that the introduction of Industry 4.0 technologies in the shipbuilding would create difficulties in the process of collecting data. These same respondents, from the shipbuilding group, mentioned that the challenge lies in the complexity of the manufacturing process that is involved in shipbuilding; a process that depends heavily on the craftsmanship of employees. This customization creates difficulties in measuring and obtaining data from this process occurring because of the uniqueness of the shipbuilding process.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to

TECH1;

According to Khan, (2015) the collection and storage of this new data poses new challenges and demands because new methodologies for storing, processing, and managing the vast amounts of data will be needed (Khan, 2015). Therefore, new models, software and visualization techniques are required to realize any actual benefits from the collected data. This creates further challenges for the future implementation and adoption of industry 4.0 technologies. The manufacturing process in the industry deals with vast amounts of data that is both structured and unstructured; in many situations the databases are not appropriately interconnected (CGI GROUP INC, 2017). To create proper business value to the final customer it is essential to enable a proper connection between these data repositories, enabling a single and unbroken data collection process woven

throughout the entire supply chain. After this is properly done, data can be stored and analyzed using technological solutions such as the Internet of Things and Big Data Analytics.

Experts Quotes:

> *"Collecting data has proven to be difficult as in many situations experienced workers such as welders do not want to be controlled in the amount of time they spend doing their work, in some situations they may look at a way to alter or change the data that is collected."*
>
> *J Pruyn*

> *"The special characteristics of a shipyard worker is also an important factor to standardise the building process because every worker takes different times to finish his work, this is because usually the work is more about craftsmanship and manual labour. Also, skilled and certified workers are difficult to find so they also do not want their work to be measured timewise, they need their space to do their work correctly.'*
>
> M Roelofs

Through the opinions of the shipbuilding experts, important insights were obtained about the specific problems inherent in collecting data through the manufacturing process. Therefore, further research is needed to establish better ways to collect data from the workers in a shipyard without employees feeling that their privacy is being affected. One example of this type of research would be doing an in-depth case study at a shipyard company, studying the deterministic actors that can eventually impact the way workers react when exposed to an environment where different aspects of their work are being measured and controlled.

Experts Quote:

> *"Industry 4.0 comes with challenges. Today, manufacturers deal with huge quantities of information, both structured and unstructured, which reside in databases that are not always properly connected. To create business value and meet customer expectations in terms of innovation, personalization and speed to market, it is necessary to connect these silos and enable a single, unbroken collection of data that is woven throughout the supply chain. In order to achieve this, the following areas need to be addressed"*
>
> (CGI, 2017)

6.2.3 TECH3: Shipbuilding relies heavily on craftsmanship to build a unique, and one of a kind, ship.

The dependence of the shipbuilding industry on highly skilled workers through the entire manufacturing chain was mentioned as a challenge by several of the shipbuilding experts. Interviewees from this group stated that highly skilled dependence creates problems in the standardization and adoption of Industry 4.0 technologies. This situation can be attributed to the following factors mentioned by the shipbuilding experts: highly skilled workers in a shipyard don't like to be measured and controlled, making the process of collecting data very difficult. Also, other experts stated that standardization of production lines would also be difficult because of the aforementioned connection with a highly skilled labor force.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to

TECH3:

The shipbuilding process is highly complicated, as Hadijna, (2015) mentions the complexity occurs as a result of the final product: ships command a very high capital value and are built for different missions, and come in different sizes (Hadijna, 2015). Because of the high complexity of such products, an equally complex shipbuilding process is also required with a large number of intermediate products, significant interdependence, and interaction between each of the activities. Often, many of the processes are not repetitive and the manufacturing input contains a vast number of components, but with a rather small number of outputs in its final products (Storch, 2007). Many of the manufacturing processes are conducted in parallel with other sub-processes, each process has different time overlaps, and many of the activities are done using different kind of technologies and techniques (Hadijna, 2009).

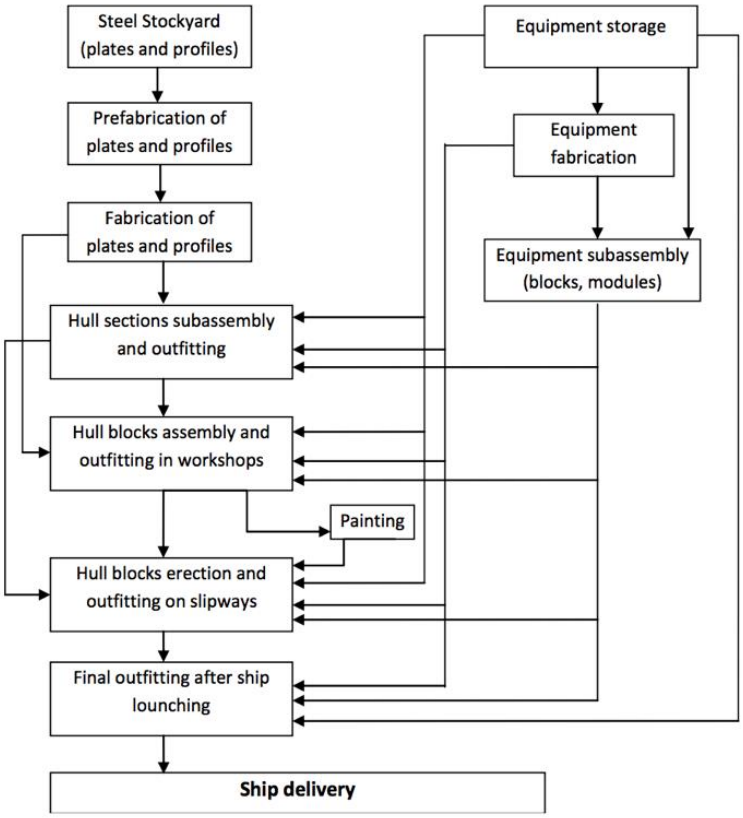

Figure 14: Complexity of the shipbuilding process. (Marko Hadijna, 2015)

As shown in Figure 14, throughout the entire shipbuilding process there is a high dependence on the skill and the craftsmanship of the workers. This reason was cited by many experts to explain the difficulties of adapting new technologies in the shipbuilding process. as through every stage the process is highly dependent on the skill set and the capacities of its workers, creating challenges in the process of adoption of technologies related to industry 4.0.

Expert Quote:

"The special characteristics of a shipyard worker is also an important factor to standardise the building process because every worker takes different times to finish his work, this is because usually the work is more about craftsmanship and manual labour."

M Roelohf.

6.2.4 TECH6: Understanding the potential cyber-risk.

In (*Figure 13*) it can be observed that Cyber Risk was the most mentioned factor affecting the process of adopting Industry 4.0 technologies. Experts from the three groups agreed on the fact that due to the interconnected nature of Industry 4.0 cyber-attacks can have drastic effects on the decision of whether or not to adopt Industry 4.0 technologies because senior management fears that their valuable information could be exposed to possible hacking.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to

TECH6:

According to a study developed by Deloitte (2016), the augmented connectivity of smart machinery and processes increases the stakes. Industry 4.0 also strives to create a union between the digital world and the physical world, driving the creation of new smart factories that enable new ways of manufacturing. These novel methods drive revolutionary changes using connectivity, which also comes with cyber risks for which the industries that are adopting the technologies are not prepared (Deloitte, 2016).

Deloitte also makes note of the fact that addressing cyber risk only at the end of any strategic decision-making process will hamper the prevention of cyber-attacks. Deloitte states that cybersecurity should be addressed as an integral segment of the strategy, and therefore it should be considered from the beginning of the design of any new Industry 4.0 initiative. Respondents from the interviews also stated the fact that, even if cyber-attacks do represent a high risk, there are also many ways that this type of risk can be controlled. One of the most mentioned ways of controlling this risk was hiring experts and consultancy companies that could help the companies to explore options that would allow them to anticipate and address the cyber risks proactively.

Expert Quote:

> *"Regarding the security of the information Industry 4.0 should have high storage capacity and high connectivity of every production process of the company, this collection of data can create certain security risks which means you have to follow strict security protocols so you make your systems robust and secure, so if you oi these steps properly your information will be secure".*
>
> *N Cantero*

Deloitte, (2016) also mentions the fact that there is no easy fix for the problem of cyber security within Industry 4.0 initiatives. Industry 4.0 technologies will support most of the production processes in a company, meaning that the risk will continue to grow as the initiatives expand in the company. Therefore, organizations need to establish response and contingency plans to accommodate the ever-present risks of the cyber environment (Deloitte, 2016).

6.3 Organizational findings related to challenges of implementing Industry 4.0 technologies in Shipbuilding.

Table 8: Organizational findings related to challenges.

Category	***Subject***	***Code***
Organization Issues. (ORG)	Top management support is necessary for stablishing any change.	**ORG1**
	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	**ORG2**
	Lack of resources	**ORG5**

In the following section, the challenges from the ***ORG*** category will be explained thoroughly, also specific quotes from each of the expert groups will be given as an example of the acquired responses.

6.3.1 ORG1: Top management support is necessary for establishing any change.

Experts from the three selected categories agreed on the fact that top management support is a crucial issue in the process of adopting new technologies. All respondents noted that many companies fail in the process of implementing digitized technologies because they lack top management support. Experts from the Industry 4.0 group, and the Technology Developer group also recognized that the role of top management support is vital for making decisions and identifying opportunities that affect the innovation process and create value for the company.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to **ORG1**:

The interaction between the roles of top management and innovation was identified and studied by researchers such as (Kim, et al., 2012) (Sharma and Rai, 2003). Both examined the effects on having top management, determining that there is always a positive effect to the process of adopting new technologies (Eshaq, 2015). Top management support plays an important role in adopting innovation by offering an appropriate environment and also making the correct decisions that enhance the execution and adoption of technological solutions successfully (Van de Ven, 1993). Top management support also provides a valuable source of encouragement for employees to embrace change, adopt new technologies, and motivate them to solve problems and adopt innovation within their processes (Jung & C Chow, 2003).

Nowadays the shipbuilding industry operates in a very complicated environment with rapidly increasing competition driven by technological change (Agbim, 2015). Companies face the need to continuously renew their way of thinking as part of the strategy needed to face the many challenges they encounter in the process of providing their final products and services. Therefore, according to Teece, (2007) this process requires a synergy creation between the technology and the organizational structure practices and processes in order to create a real competitive advantage (Teece, 2007). The role played by top management is crucial to the process

of creating the necessary synergy in order to successfully implement new technologies in a company.

Experts Quotes:

"Industry 4.0 should be developed in a high senior level, developing strategies that change the mentality on how people see these technologies. As many projects fail at beginning because of a lack of proper support of senior level management."

A Sparrow

"Top management support is essential for the survival of the adoption of innovation or any new technology as the process requires commitment to change."

M Sorensen

6.3.2 ORG2: Companies need to change the structure to adapt, creating new divisions, teams, or departments to support the implementation of new technology.

Organizational structure is an important issue in the process of adopting new technologies and was often mentioned by several experts within the three categories. They frequently stated that highly rigid organizational structures can hinder the process of adopting new technologies. In some cases, experts mentioned the fact that companies have failed in the transformation process because they were simply adding new functions and work to their employees, and that communication became too difficult in these highly structured organizations. Experts also argued that changes in organizational structure need to be made in order to adapt and achieve organizational goals, defining organizational structure as a framework that is used to distribute resources and tasks, in addition to the work will be distributed across different division and departments. The perspectives of the respondents regarding the influence of organizational structure in the process of adopting innovation is deemed important, especially considering the fact that many respondents agreed on the point that hierarchical classical organizations hinders the transformation process toward the implementation of new technologies.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to

ORG2:

Chen (2007), mentioned that companies that have invested in information technologies have shown an increase of decentralization, and therefore a reduction of the formality in the structure of the organization, yielding a positive effect on the complexity of adopting new technologies within their processes.

Also, Mintzberg (2003), mentions that highly structured and pyramidal organizations are very slow and inflexible and can also be sluggish in deciding to develop and adopt innovation. It is argued that under new competitive paradigms, a company organized under classic concepts with standardized processes will not adequately foster flexibility and agility in decision making, thereby hindering cooperation and communication between employees (Jensen & Johnson, 2007).

Expert Quotes:

"The culture of a company also has a big influence on how they adapt the technology, because the company needs to influence and modify every single department of the company if the technology is not accepted in every department and integrated the Industry 4.0 technology will not work."

H Munz

"Larger companies should organize in collaborations teams with a more divisional and matrix organization. Large structural organizations are usually reluctant to change. Change is necessary for bigger companies because they have to adopt."

B Gobilliard

6.3.3 ORG5: Lack of resources.

The development and adoption of any of the Industry 4.0 technologies may require substantial investments as mentioned by many of the experts from the three main categories. They consistently pointed out that lack of resources is one of the biggest challenges towards the implementation of

industry 4.0 technologies. In some cases, it was also mentioned that any investment in these types of technologies can be seen by senior level management as asymmetric between the costs and the benefits arising from implementation of new technology. Industry 4.0 technologies related to digital transformation usually require large investments, in which profitability will often occur only over a medium, to long, timespan. Shipbuilding companies may not have the resources available to make this type of big investment, especially considering the fact that usually the more radical the technology and the changes to the manufacturing processes, the greater the initial costs of the investment. This increases the uncertainty for investors, as certain parameters, such as the return Over the investment (ROI), become difficult to accurately predict. This discourages shipbuilders from investing in Industry 4.0 technologies.

Next, a confirmatory validation step will be made to corroborate actual findings in the next paragraph; thus, additional literature will be introduced and used to corroborate findings related to

ORG5:

According to Rio, (2004) the adoption and implementation of new technologies can lead to drastic changes in actual production processes and in the organization of a firm; this type of structural change usually comes with substantial retraining of the workforce in the new technologies (Rio, 2004). This means that the cost of switching to a new technology will be higher because the new technology might not be backwards-compatible with the current systems and processes. Rio also mentions the fact that the more radical the break with current know-how, the greater the up-front investment. The shipbuilding process involves a complex technological system with many independent parts, and ships, built in several different geographic locations. This means that changing one segment of production will also induce changes in other production segments and sometimes throughout the entire production system. Such changes are generally very expensive, and represent a challenge in the decision-making process in adopting Industry 4.0 related technologies (Hadijna, 2015).

Expert Quote:

"Access to financing is yet another important factor for a capital-intensive industry like shipbuilding. Financing (especially by arranging guarantees) is both important for shipbuilders in arranging pre-delivery financing as for buyers. The current financial crisis has a relatively strong impact on the financing of both shipyards and ship owners."

J Spee

6.4 Environmental Findings related to the challenges in implementing Industry 4.0 technologies in shipbuilding.

Table 9: Environmental findings related to challenges.

Category	***Subject***	***Code***
Environment (ENV)	There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	ENV2

In the following section the most evident challenges from the ***ENV*** category will be explained thoroughly, also specific quotes from each of the expert groups will be given as an example of the acquired responses.

6.4.1 ENV2: The relation between Government policies and the way companies adopt Industry 4.0 technologies

According to the interviewed experts, government policies play a vital role in the decision-making process of companies considering adopting Industry 4.0 technologies. However the insights offered by the respondents were not enough to determine the direct effect that the role Government has on the process of adopting technologies. These responses, therefore, do not lead to answers for questions such as: what role does the government play in technological adoption across industries? Or: how does the interaction take place between companies and governments during the development of policy? Or: what type of policies encourage companies to adopt industry 4.0 technologies?

Answering these questions is a very important step toward understanding the role of government in the process of adopting industry 4.0 technologies because the state is becoming more involved in Industry 4.0 and the diffusion of its technologies through the use of tax exemptions and the developments of regulatory programs. This approach was mentioned by some of the experts during the interviews because these types of policies can eventually help companies reduce the risk on the investment.

6.5 Conclusions:

The main aim of this thesis was to investigate the main challenges that significantly influence and affect the process of adopting Industry 4.0 technologies in the shipbuilding industry. The results show a total of seven factors that have an important impact on the adoption of Industry 4.0 technologies in the shipbuilding industry. Also, these findings show that it is not only technological barriers that have a significant effect on the decision-making process of adopting an Industry 4.0 technology, but also organizational and environmental. It is also clear that many of the current processes and interactions within the shipbuilding industry will need to be changed to embrace the development of new technologies where complex hierarchical structures will be replaced by organic structures characterized by cross-sectional teams working on the implementation of Industry 4.0 technologies.

Also, it is evident in the results of the coding scheme that the shipbuilding industry varies considerably from other industries. Some of the engineering processes present in the shipbuilding industry can be compared with others, but there are still many barriers because of specialized techniques and processes used in the industry.

EXPLORATIVE RESEARCH:

PART II: Moving forward towards digitalization in the Shipbuilding sector.

Figure 15: COTECMAR aerial photography.

During the second part of the explorative research the success factors towards implementing Industry 4.0 technologies were analyzed, a possible road map is proposed to help shipbuilding companies in the transformation process towards adopting digitized technologies.

7.Suggested roadmap towards a successful implementation of Industry 4.0 technologies in Shipbuilding.

This chapter proposes a roadmap for the successful implementation of Industry 4.0 solutions in the shipbuilding sector. A total of five findings were obtained from the encoding scheme derived from the expert interviews. Where questions such as: *"What recommendations would you make to a shipbuilding company that is willing to start the transformation process?"* were developed in order to search for in-depth solutions and recommendations that can encourage the process of adopting Industry 4.0 technologies in the shipbuilding sector.

7.1 Selection of success factors.

This chapter analyses possible suggestions for successful implementation of Industry 4.0 in shipbuilding. The results from the encoding scheme are also considered and analyzed comprehensively. In section 7.2 the frequency of occurrence of these factors in each of the interview is discussed further. Finally, in section 7.3, each of the success factors will be explained in depth.

Table 10: Identified success factors.

Category	**Subject**	**Code**
Technology (TECH)	Mapping the process that wants to be improved in the shipyard.	**TECH2**
	Think about technology that enhance human performance.	**TECH4**
	Start with small projects to have fast success then move to bigger projects.	**TECH5**
Organizational (ORG)	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology	**ORG4**
Environment (ENV)	Making strategic alliances	**ENV1**

7.2 Highest frequency success factor.

As shown in (*Figure 16*) success factors are distributed among the three groups of experts. The importance of each of these TOE framework categories (Technology, organization and environment) is also notable, because each of these categories was determined to be relevant according to the frequency distribution and occurrence of each of the factors. It is also observed in (*Figure 16*), that the findings related to **ORG4** are the most mentioned by experts. There, the interviewees from both the shipbuilding group and technology developers group agreed that shipbuilding companies needed to make changes in the structure of the organization to facilitate the process of adopting Industry 4.0 technologies. During the interviews, the experts mentioned examples of how shipbuilding companies could change their structure such as: creating special divisions dedicated to research and development of Industry 4.0 technologies and harmonizing the technology with the manufacturing process within the company. Additionally, it was also mentioned by the experts that with the implementation of cross functional teams, a shipyard could gain from the experience of employees with different backgrounds to integrate the technologies within the internal processes of the company.

Also, it can be observed in (Figure 16*)* that the frequency of responses in **TECH2** and **TECH4** are more often mentioned by the Industry 4.0 expert group This seems to be in line with the knowledge and experience of the Industry 4.0 group, who specialize in offering practical recommendations for the implementation of these technologies. This provided the first approach concerning the development of a roadmap for implementing Industry 4.0 technologies in shipbuilding. On the other hand, a contrast was observed with **TECH5** findings: shipbuilding experts and technology developers agreed on the suggestion that, when beginning the transformation process. shipbuilding companies should begin with small projects. Finally, it can also be observed in *(*Figure 16) that findings related to **ENV1** category were frequently mentioned by experts from the three groups, suggesting a strong importance in developing strategic alliances to facilitate the process of adoption of Industry 4.0 technologies.

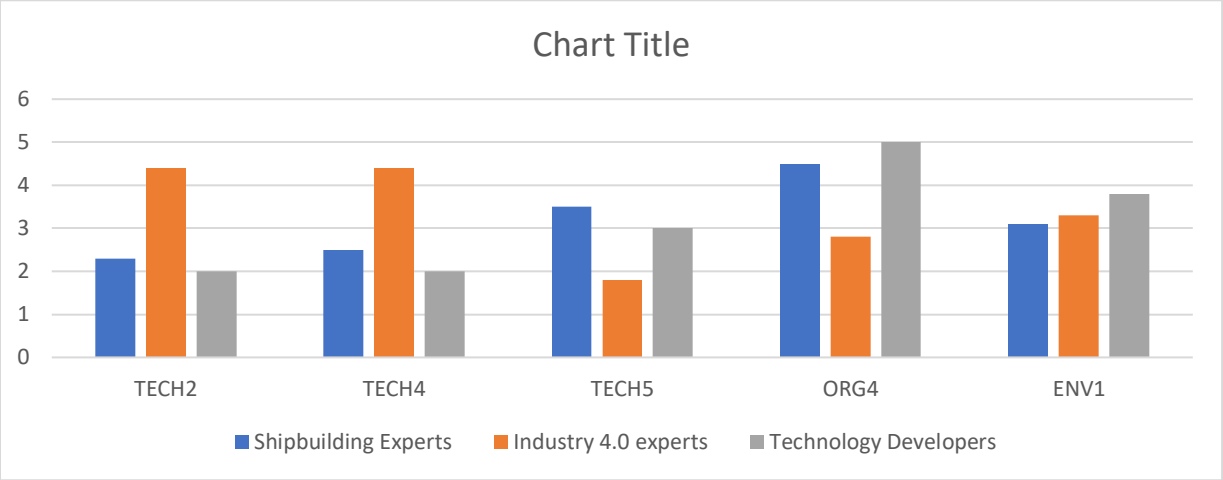

Figure 16: Frequency of obtained success factors.

During the final segment of the interviews, questions were posed to gain general recommendations on how a shipbuilding company could begin a successful transformation process towards the implementation of Industry 4.0 technologies. A series of steps were derived from the coding scheme as shown in (Figure 17):

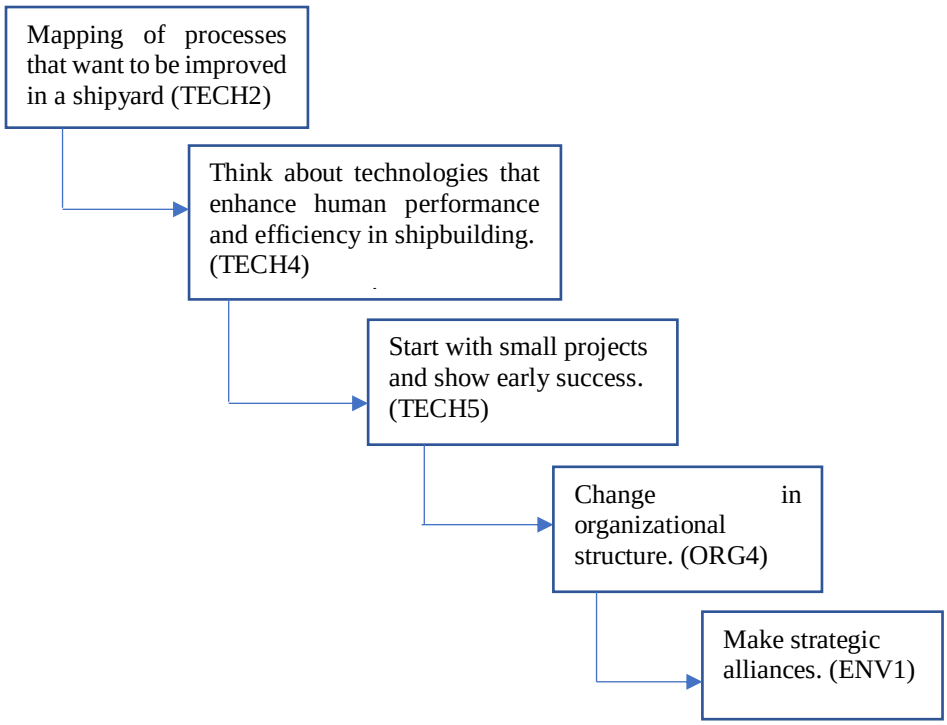

Figure 17: Derived steps for a successful implementation of Industry 4.0 technologies.

7.1 TECH2: Mapping processes that should be improved in a Shipyard.

Experts from the Industry 4.0 group mentioned that many companies fail to incorporate digital technologies mainly because of a lack of understanding of their actual processes. Another important aspect mentioned by the experts is that companies acquire different technologies without understanding how it will actually help the company fix a specific problem or be more efficient. As a consequence of this uncertainty, the updates sometimes fail. Therefore, a maximal understanding of the shipbuilding process is needed, requiring the incorporation of specialists with different backgrounds, including shipbuilding experts and Industry 4.0 technology experts. In this way, complementarity could arise in two ways: Firstly, because the nature of the cross functional team means more knowledge is accessible, and can be used to understand in what part of the manufacturing value chain of the shipbuilding process the technology can be incorporated to improve efficiency. Secondly, after a clear understanding of the area that needs to be improved is reached, each team member can capitalize on the experience of others to integrate the technology within the manufacturing process of the shipyard.

Many experts also agreed on the fact that digital transformation and the implementation of Industry 4.0 technologies is not something that can be achieved overnight or in a short period of time. Therefore, a strategic approach is needed to accomplish the company's objectives for adopting industry 4.0 technologies. This means that it is essential that companies develop a strategy to implement Industry 4.0 technologies, because each of these decisions should be an integral part of their business process. Hence, experts emphasized that companies wishing to begin the transformation process needed to map their current situation first in order to better understand the benefits of implementing the new technology. It was also suggested that shipbuilding companies focus on implementing technologies that can solve actual problems or eliminate waste in the production process. Helping shipyards to also understand and identify where they have their most significant problems could yield the most business value being a crucial step at the beginning of the transformation process.

Later, confirmatory literature research was done to corroborate these and to explain the necessary steps a company should look into when beginning to map their processes.

In a study developed by Cognizant, (2016), it was argued that three things are critically important when developing a digital transformation strategy (Cognizant, 2016):

Do your research before solving the problem: Cognizant argues that in-depth research is needed to further understand and explore actual business problems, and, therefore, to find opportunities to improve actual difficulties. To do so, they argued that experts from different backgrounds need to work closely with stakeholders, involve consultancy companies, and designers of technologies to grasp the extent of the problems in the company. This leads the company to the selection of a proper technology that truly fits their needs (Cognizant, 2016).

Pay attention to the business environment: Cognizant also discusses that understanding the main problem is just one factor in a successful approach to such technology upgrades. A complementary factor is to search in the business environment. Understanding what the competitors are doing, or what other companies have done to implement Industry 4.0 solutions, can help companies relate their internal problems with actual disruptions in the market (Cognizant, 2016)

Put the customer in the center*:* Finally, Cognizant mentions that an important part of the digital strategy is that companies should focus on their customers' needs first and *then* they should focus on the product. This means that after companies have a clear understanding on the market needs they can make better decisions regarding which segments of their business they should change or where they should implement new technologies.

Expert Quote:

> *Companies analyse where are there current problems, understanding where they have more waste, after they are clear, companies can start making small improvements in the company to solve the mapped problems.*
>
> R Rouzbeh

7.2 TECH4: Think about technologies that enhance human performance in shipbuilding

Based on the conducted interviews, one aspect that was repeatedly mentioned by the experts is the fact that many companies that are beginning to incorporate digitized processes fail to understand that technologies should be intended to improve an augment human labor and not to replace them. The experts suggested that companies should gain a better understanding of the technologies that can further improve business value and also incorporate and challenge employees technological commitment, helping the company to improve efficiency. One way of accomplishing this in a work setting mentioned by Lima, (2018) is that people should put "emphasizing transparency" first (Lima, 2018). Companies should communicate adequately how the changes will impact each of the work settings with their employees. Arguably, this will create awareness of what is coming next, how it is going to look, and how it can impact working efficiency; understanding this context would help employees understand the need for change.

Expert Quote:

"The real motive that has incentivized the appearance of all these new tools and technologies is the appearance of the human being as the center of everything."

J Inoges.

7.3 TECH5: Start with small projects, show success, then move to bigger projects.

According to the frequency of the expert's responses shown in (*Figure 16*) many interviewees agreed on the fact that the best way for a shipyard to start in the implementation of Industry 4.0 technologies is beginning with small projects that can further be used to demonstrate early success. Also, the application of these technologies in a shipyard will allow the development of vertical integration, evolving alongside IT and communications systems and permitting higher connectivity between employees, customers, and machines. Also, the implementation of these technologies will help shipyards to improve the integration of the value chain of production, thereby incorporating improvements from the initial design phase of the ship through the

construction phase and all the way through the life cycle of the ship. For the purpose of comparison, a series of examples of Industry 4.0 technologies that can be used in shipbuilding as small projects to show success will be presented in subsection 7.3.1. Finally, one technology will be furtherly analyzed in Chapter 8 as a practical application of the technology in shipbuilding.

Likewise, experts mentioned that, when starting the transformation process, companies should not begin with massive changes in their production line, they should, instead, start with small changes to demonstrate that the technology works. If they can demonstrate the early successes in the implementation of the technology it will be more easily accepted in other sectors throughout the value chain of the company. Consequently, this will also bring the attention of senior management to continue investing in the technologies that had produced positive results.

Later, confirmatory literature research was done to corroborate these and to explain the necessary steps a company should look into when beginning to map their processes.

In a study performed by McKinsey (2005), it was discovered that many companies run into difficulties when adopting innovation because they struggle to decide which ideas should be actually supported and then scaled. According to McKinsey (2005), during this transformation process, companies should set smaller projects in motion that can further demonstrate, in short time, an early Return on Investment (ROI). They also argue that it would be much easier to kill the project if it was not working correctly.

Expert Quote:

> "*When starting the transformation process companies should not start with huge changes in their production line, they should start with small changes and demonstrate that the technology work, if their a success with the implementation of the technology or the collection data it should be implemented in another sector"*

J Inoges.

7.4 ENV1: Change in organizational structure.

As shown (*Figure 16)*, the findings related to **ORG4** is the most mentioned factor by experts, where the interviewees from shipbuilding group and technology developers agreed that shipbuilding companies need to make changes in the structure of the organization to facilitate the process of adoption of Industry 4.0 technologies. During the interviews, the experts mentioned examples of how shipbuilding companies could change the structure such as; the creation of special divisions dedicated to research and development of Industry 4.0 technologies and harmonizing that technology with the existing manufacturing process within the company.

Also, experts mentioned that most of the companies that have been demonstrably successful in the practice of adoption and fostering innovation are those in which the development and sharing of knowledge using formal research practices, experience, interaction and sharing of knowledge between employees is promoted. During the interviews, it was also indicated that traditional and hierarchical organization structures are not appropriate for companies wishing to begin the transformation process toward the implementation of digitized technologies related to Industry 4.0.

Therefore, it is understood that if shipyards want to incorporate and foster Industry 4.0 technologies, more flexible and agile structures are required to permit a positive communication and interaction between employees without the rigidity of over defined hierarchies. This organic type of structure is needed to allow the integration of new technologies within manufacturing process in the shipbuilding industry. It can be argued that this integration finally leverages the organization's innovative capacity. However, the findings from the interviews cannot be seen as confirmatory of the influence of organizational structure in the process of adopting innovations. Further studies would be required to verify the results in a shipyard setting. An example of the type of study that is needed would be a case study in a shipyard where the actual findings could be compared in reality.

Later, confirmatory literature research was done to corroborate these findings and to further explain the necessary steps a company should look into when beginning to map their processes.

Brjolfsson, (2002), stressed the fact that companies that had been successful in adopting new technologies were generally more willing to adopt work practices that involve the creation of independent work teams, decentralization, and the creation of new divisions. The creation of new teams creates a synergy between the organizational structure and the adoption of the technology. Al Harahseh, (2006), also emphasizes, in his study, that organization support affects the adoption of innovation, affirming that there is a direct impact of the organizational climate on the adoption of innovative technologies. Overall, it can be stated that companies wishing to pursue innovation and adoption of new technologies need more flexible and agile structures.

7.5 ENV2: Making strategic alliances.

Because of the unique characteristics of Industry 4.0, associated technologies require a change of workforce, or demand new skills and roles and huge investments, many of the interviewed experts considered cooperation and the formation of strategic alliances across firms to be an essential requirement for the successful adoption of Industry 4.0 technologies. However, experts stated that while strategic alliances were considered necessary on the whole, there are also many factors that may dissuade companies from searching for strategic associations. Some of the mentioned factors were: shipbuilding companies manage high degrees of confidentiality in their work, and many shipyards are not keen in changing their way of working.

Later, confirmatory step using literature research was done to corroborate these findings and further to explain the necessary steps a company should look into when beginning to map their processes.

Scholars such as Man & Duysters, (2005) recognized the importance of collaboration across firms for the purpose of developing new technologies. Some of the reasons for this trend are due to the intensification of competition in global markets and also continuously increasing technological change (Man, 2005) (Lambe, 1997). Similarly, by enabling the different

organizations, to integrate internal and external resources, strategic alliances can positively influence the efficiency of organizations (Faems, 2005). Consequently, R&D can be shared with strategic alliances, splitting the risks and the cost of the investments, and allowing companies to enter into more significant innovation projects while distributing the risk. Overall, it can be argued from the empirical data from the interviews and literature review, that the formation of a strategic alliance is a crucial step in the process of adopting new technologies, and can be a valuable tool for shipyards willing to start a digital transformation phase to incorporate Industry 4.0 technologies within their processes.

Expert Quotes:

> *"Strategic alliances are important but companies should be very critical in the company you go to, so you should look for really specialists in the area and companies that have similar production facilities and experience with the technologies."*
>
> *J Inoges*

> *"Strategic alliances are very important on helping the process of change. Northern shipyards have been doing this for years looking for other shipyards that can help each other to have extra profit, they can benefit from the expertise of each company. Reaching out for other companies is important as they can specialize in certain areas and can jointly work on bigger projects."*
>
> *J Pruyn*

7.6 Conclusions.

The second part of the explorative research has led to the proposal of five success factors towards the implementation of Industry 4.0 technologies that were obtained from the encoding scheme. These results represent a general perspective for a company wishing to begin the transformation process towards digitized technologies. Starting from mapping the current situation of the company and developing a strategy that fits the company's interests. Then, it was also

recommended by experts that companies should think about their workers first, asking themselves how the technologies help their employees to become more efficient. Thirdly, companies should develop small projects that could enable them to demonstrate early success, as such concrete evidence could better encourage top management to continue investing in related Industry 4.0 technologies. Finally, it was discussed that companies wishing to pursue innovation and adoption of new technologies require more flexible and agile structures.

8.Example of an Industry 4.0 technology in a Shipbuilding setting.

In this chapter, an example of an application of an Industry 4.0 technology in the shipbuilding sector will be given. This is intended to help to answer the sub-question; *"How can a shipbuilding company apply an Industry 4.0 technology within its manufacturing process?".* To answer this question, a methodology developed by Lee & Bagheri, consisting of a 4C level architecture used to design a Cyber-Physical System, was implemented (Lee, 2014).

The general method used to make the design is based on the paper developed by Hartog & Verschuren (Hartog & Veschuren, 2005). In the first segment, a general description of the problem will be given, where the distinctive characteristics of the industry will be explained. Secondly, the problems encountered by a shipbuilding company will be explained. Third, the goal of the research will be defined. Fourth, the boundary conditions of the design will be explained. Finally, the conceptualization of an application of a Cyber-Physical System in a Shipbuilding setting will be introduced, assessing the 4c level architecture methodology developed by (Lee & Bagheri, 2014).

8.1 Applicability of Industry 4. Technologies in a Shipyard setting.

During Chapter 3 it was mentioned that the grounds of Industry 4.0 technologies could be further transferred to a shipyard setting, giving birth to a Smart shipyard s. In this type of production setting, the engineering processes and resources are e entirely integrated, making the production process more efficient and more flexible by using real-time monitoring and control. During the production process, Industry, 4.0 technologies will help to improve processes through self-optimization and automatic decision making in the design cycle (NAVANTIA, 2015). Shipyards also face similar challenges to other industries as mentioned by Wang, (2013) who classified the differences between three main categories; The horizontal integration of a new generation of networks, the vertical integration in the production system and the implementation of technologies requires re-engineering of the production processes within the plant (NAVANTIA, 2015). The horizontal integration in the value creation of networks is fundamental in allowing customization

and changes in the manufacturing process in a short time. The second challenge is related to the vertical integration of the production system. The change in the vertical chain allows the production systems in the shipyard to become more efficient. Finally, the third challenge is related to a complete digital integration through the entire value chain of production, starting from the design and continuing through until after sale. (Wang, 2013).

To accomplish this level of integration implies the introduction of new disrupting technologies that can further change the entire value chain of production of a shipyard setting. Such disruptive technologies might include: artificial intelligence, machine learning, robotics, enhanced reality systems, the application of drones, 3D and 4D printing among many other technologies. According to Navantia, (2015) by implementing these Industry 4.0 solutions, a shipyard can leverage smarter efficiency consumption, reduce waste, and improve its inbound and outbound logistics (NAVANTIA, 2015).

8.1.1 Applications of Industry 4.0 projects in shipbuilding.

- ***Collaborative Robotics:*** The application of collaborative robotics will allow the improvement of robot-human interaction, helping to reduce the risk of hazardous tasks, or in other cases to reach confined places that are difficult to access by employees.
- ***Additive Manufacturing:*** The application of 3D printing will help shipyards to manufacture complex components developed from base 3D model without the need of specialized and expensive equipment.
- ***Big Data Analytics:*** Big data analytics will allow the extraction and interpretation of vast amounts of data that is produced throughout the value chain of production of the shipyard. The interpretation of the data will allow further improvements in the shipbuilding process, beginning with the design of the ship, continuing through production and the rest of the life cycle of the ship.
- ***Internet of Things:*** The incorporation of the Internet of Things into shipbuilding will allow the intercommunication of stakeholders connecting employees, customers and facilities, allowing the use of geographically distributed supply chains.

- ***Virtual Modeling and digital twin:*** the development of virtual modeling technologies and digital twin will help to optimize the integration of the production system of the ship through the entire life cycle of the ship, from the initial design of the ship until operation and decommission.
- ***Virtual Reality***: With digital connection with the physical world, the employee will have access to vast amounts of data directly in their line of sight, allowing access to real time data of different components.

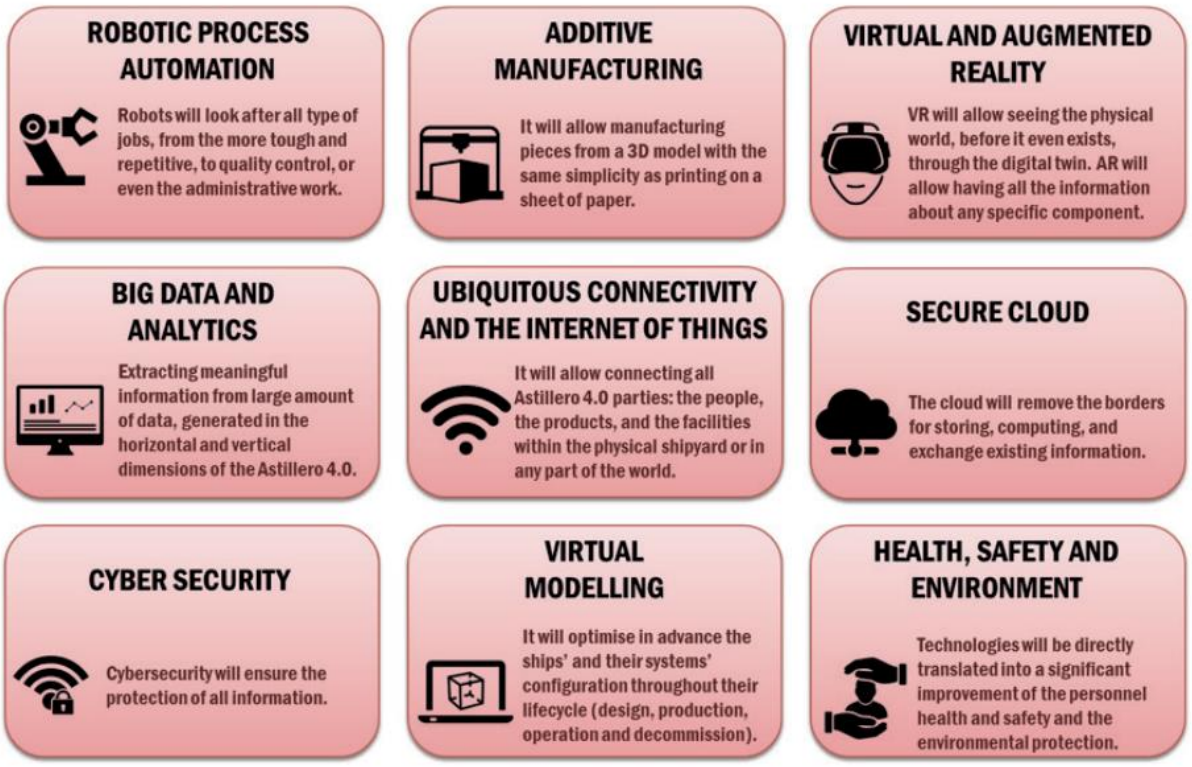

Figure 18: Smart technology applications. (Recaman, 2018)

8.2 Problem definition.

According to Navantia,(2015) the construction of pipes constitutes a significant proportion of the shipbuilding process. Ships can require between 13,000 and 35,000 pipes according to its dimensions and functionalities; the functions vary from cooling systems in central and auxiliary machinery to drinking and wastewater (NAVANTIA, 2015). Also, pipes are built using different

types of materials and in many different shapes which means it is necessary to maintain traceability and location of each of the pipes that are being developed throughout the entire construction process. The complexity of the installation of piping in the shipbuilding process serves as an example of the need to incorporate new technologies that could provide a reliable monitoring and selecting system to facilitate the selection and the building process for the workers and welders.

8.2.1 Layout setting of COTECMAR Shipyard

At the end of the construction process, pipes are located in a general storage area this is process is done according to the production planning. As soon as the cutting and welding procedure is finished, pipes are stored in a facility within the work shop as shown in (*Figure 19*). After all the welding and bending is finished, the pipes are finally galvanized (a process done on steel pipes to prevent future corrosion). During this process, all initial markings and identification of each of the pipe spool is erased. After this there is no easy way for workers to clearly identify the traceability of the pipe and where it's going to be finally installed.

Figure 19: Pipe building process in COTECMAR shipyard

Figure 20: Pipe building process in COTECMAR shipyard

After the spools are properly galvanized and stacked, workers have to identify each of the spools of pipes manually, meaning that workers spend a significant amount of time measuring and identifying the correct segment of pipe to be installed on the ship as shown in (*Figure 20*). This process is sometimes difficult and time consuming, and it can also be susceptible to human errors.

Figure 21: : Installation of pipes of a ship in COTECMAR shipyard

Figure 22: Installation of pipes of a ship in COTECMAR shipyard.

8.2.2 Design of a better pipe installation system.

The main prerequisite of the tool is that it should reduce the time of selection and identification of pipe spools during the manufacturing process. The proposed technology is based on enhanced reality through the application of Cyber Physical Systems. This type of smart identification systems for pipes can provide workers a faster, and more reliable way of identifying pipes. The implementation of an enhanced reality tool could also help to increase the efficiency in the production system, yielding considerable economic benefits for the shipbuilding company. At the shipyard considered during the present study, the identification of pipes after they are built is achieved mainly by visual check and experience, meaning that, in some cases, workers could mistakenly select the wrong segment of pipe. The proposed Enhanced Reality systems will offer workers dynamic information regarding the dimensions of the pipes to reduce the possibility of mistakes, thus allowing an easier identification of piping segments preventing mistakes in the selection process.

Figure 23: Enhanced reality device.(Navantia, 2016)

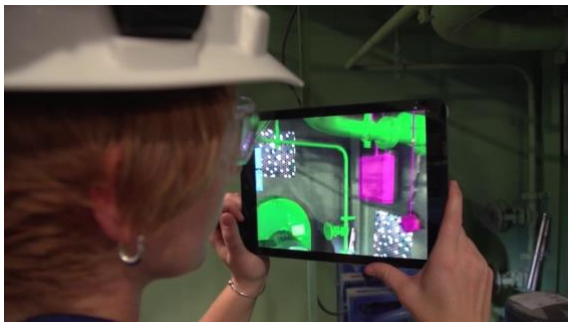

Figure 24: Enhanced reality device.(Navantia, 2016)

8.3 Conceptualization of the design.

As established in the previous section, the design should allow workers to automatically select the correct pipe, while also having a dynamic measuring system allowing real time feedback to the production system. To fulfill these requirements, the proposed system would be an Enhanced Reality Cyber Physical System with the following characteristics: The system would allow the worker to select the correct pipe locating the segment according with its dimensions. Also, the system should allow a real time quality control check that can further be introduced in the feedback loop in the pipe building process to correct future flaws.

8.4 Guide towards designing an Enhanced Reality Cyber Physical System

For the design of the Enhanced Reality a methodology was used developed by Lee & Bagheri for making Cyber Physical Systems in 4 steps or levels, starting from connectivity, conversion, cyber and cognition (Lee & Bagheri, 2014).

LEVEL 1: Connectivity

Connectivity is a crucial part of Cyber Physical Systems. Thus, in the 4c methodology developed by Lee & Bagheri has two important considerations: First, how the system will collect the data from the physical world, and secondly, the protocol used to collect the data.

8.4.1 Sensors: Gathering data from the physical world.

The sensors are used to gather the data from the physical world; virtual images will be projected towards the visual field of the final user while the worker is in front of the work site. Images will be projected on the worker's visor and the software will automatically measure the shape of the pipes until there is a correct match with the spool that is required.

Figure 25: Enhanced reality system developed by Microsoft.(Microsoft, 2017)

LEVEL 2: Conversion stage

In the second, conversion stage, the Cyber Physical System can properly organize, convert and store the data coming from the visors so it can be further analyzed by the software and introduced. The platform used is crucial because it contains the software package that feeds the lenses with the dynamic measures of the pipes that can be automatically detected when there is a correct match.

LEVEL 3: Cyber

According to Lee & Bagheri, the "cyber" level can help to analyze, store, and further monitor the data that was collected in the previous stages (Lee & Bagheri, 2014). During this stage other types of Industry 4.0 technologies and techniques can be used in combination with the Enhanced Reality system such as Big Data Analytics and Internet of Things. This stage is also critical because it allows communication throughout the value chain of the construction process of the pipes, meaning that if the sensors identify a flaw in the pipes, the information can be analyzed by the system and later correct the mistakes.

LEVEL 4: Cognition

According to Lee & Bagheri, (2014) the "cognition" level in a Cyber Physical System can help to optimize a process learning from previous mistakes, thereby generating a base of knowledge after experience. Reaching this level of Cyber Physical System could help the pipe building process in a shipyard to prioritize solutions while optimizing the construction process (Lee & Bagheri, 2014). Jimenez, (2016) argues that this capacity can only be reached using advanced Artificial Intelligence (AI) algorithms in which a bi-directional interaction is created from Machine to Machine and also from Machine to Human (Jimenez, 2016).

8.5 Possible impact of using enhanced reality in a shipyard.

It is argued that the presented example of an Industry 4.0 technology application in a shipyard could improve efficiency in the production system.

The presented Enhanced reality tool established as a Cyber Physical System could help shipyards to reduce the amount of paper used in workshops and allow a quick identification of the pipe systems with the minimum possible error in order to avoid re-process. A system like that described above, should allow the worker to identify the traceability of each of the pipes according to its measures until the final location where it will be installed on of the ship is found. The system

should also work as a quality control system identifying possible fabrication mistakes that could be automatically corrected later in the design process.

Finally, a comparison of the results was done to compare the presented Industry 4.0 technology example with the steps to a successful implementation of an Industry 4.0 technology in a shipyard setting. This step was done to better comprehend the applicability of the presented road map in a real setting.

8.6 Using TECH success factors to compare the applicability of the technology with the findings obtained in Chapter 7

Identified findings regarding success factors towards the implementation of Industry 4.0 Shipbuilding technologies

Category	***Subject***	***Code***
Technology (TECH)	Don't think about the technology first, think about the process.	**TECH2**
	Think about technology that enhance human performance, not replace them.	**TECH4**
	Start with small projects to have fast success then move to bigger projects.	**TECH5**

Figure 26: TECH findings regarding success factors.

8.6.1 TECH2: Don't think about the technology first, think about the process.

Experts highlighted the need for companies to map their current situation to fully understand the benefits of implementing the new technology, helping the companies to focus on implementing technologies that can solve actual problems or to eliminate waste in the production process. It's necessary to understand the pipe building process to recognize which areas need to be improved in order to increase the efficiency in production and also avoid rework and re-engineering of processes.

8.6.2 TECH4: Think about technology that enhances human performance, not tech that replaces them.

Technology should be used to improve and augment human labor, not to replace them. Experts mention the fact that companies should gain a better understanding on the technologies that can further improve business value and also incorporate and challenge the employee's technological commitment. Enhanced reality devices are designed to improve worker's efficiency by helping them save time measuring the different segments of the pipes, reducing the chance of selecting the wrong pipe, and reducing the time of rework activities.

8.6.3 TECH5: Start with small projects to have fast success then move to bigger projects.

As mentioned in previous chapter when starting the transformation process towards Industry 4.0 technologies, companies should not begin with large changes in their production line; they should, instead, start with small changes and demonstrate that the technology works. If they can demonstrate the early success of the implementation of the technology, it can be further developed in other sectors throughput the value chain of the company. The enhanced reality is a perfect example of a technology that would not alter the production line of the shipbuilding company. Also, the ER project can be used as to demonstrate the success of small ventures towards the implementation and adoption of bigger projects.

9.Conclusions and Recommendations.

The conclusions of the thesis are discussed in this chapter. First, the answers to the main research questions will be presented. The conclusions about the research and the methodologies will also be introduced. Finally, practical recommendations will be made in combination with suggested further research.

9.1 Research Question 1

RQ1: What are the main challenges of implementing Industry 4.0 technologies in Shipbuilding?

A total of seven challenges were obtained from the encoding scheme derived from a set of 23 interviews involving shipbuilding experts, Industry 4.0 experts, and technology developers. The results were separated into three main categories according to theoretical model the TOE framework (Technology, Organization and Environment) developed by Tornatzky & Fletcher (Tornatzky & Fletcher, 1990). The challenges were divided across each of the categories.

These challenges vary from data collecting problems, to the Uniqueness of the Shipbuilding Process, Cyber risk understanding, Top management support, cultural structure, lack of resources, and the implication of Government Policies. Each of the selected challenges was considered important by the group of experts, and helps to understand the difficulties of shipbuilding companies wishing to begin a transformation process towards digitized technologies within the manufacturing process. The results can also be transferred to other industries that share the uniqueness of the shipbuilding process, and the involvement of craftsmanship in their manufacturing process.

The results also show that the challenges are not only related to the technology by itself but other factors such as organizational and environmental factors were also deemed as important confirming the applicability of the theoretical model used for the present thesis the TOE framework.

Table 11: General findings towards implementation of Industry 4.0 technologies.

Category	*Subject*	*Code*
Technology (TECH)	Problems collecting data from production process	**TECH1**
	Shipbuilding depends on craftsmanship, building unique and one of a kind ships.	**TECH3**
	Understanding potential Cyber risk	**TECH6**
Organization. (ORG)	Top management support is necessary for stablishing any change.	**ORG1**
	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology.	**ORG2**
	Lack of resources	**ORG5**
Environment (ENV)	There is a relation with Government policies with the way companies adopt Industry 4.0 technologies	**ENV2**

9.2 Research Question 2

RQ2: What strategies should a shipyard implement for a successful implementation of Industry 4.0 technologies in the shipbuilding industry?

A total of five success factors contributing to the successful implementation of Industry 4.0 technologies in the shipbuilding sector were identified from the encoding scheme, the derived recommendations as shown in (table 11) can be considered as a general roadmap for shipbuilding companies wishing to begin the transformation process towards digitized technologies related to Industry 4.0. The recommendations start for companies needing to focus on developing a complete digital strategy and therefore mapping their current situation to fully understand the benefits of implementing the new technology and the problems that need to be solved within the company. One of the most repeated aspects mentioned by experts during the interviews was the fact that companies wishing to start the transformation should put their employees in the middle of the decision process, considering about technologies that enhance their performance and efficiency and not replace employees.

Thirdly, shipbuilding companies should begin with small projects, making only minor changes at first that do not affect or compromise their production line directly. As aforementioned,

demonstrating early success can lead to the implementation of other projects and also bring attention of top management to continue investing and supporting the developments of these type of projects. Also, proving early success can enable the company to secure future funding for other projects. However, it is important that companies target a confined scope for the development of their projects. Finally, it was also found that the implementation of projects should be done by creating cross-functional teams fully committed to the execution of the project and with a clear communication channel with top management.

Table 12: Success factor towards implementation of Industry 4.0 technologies.

Category	***Subject***	***Code***
Technology (TECH)	Don't think about the technology first, think about the process.	**TECH2**
	Think about technology that enhance human performance, not replace them.	**TECH4**
	Start with small projects to have fast success then move to bigger projects.	**TECH5**
Organizational (ORG)	Companies need to change the structure to adapt, creating new divisions, teams or departments to support the implementation of the technology	**ORG4**
Environment (ENV)	Making strategic alliances	**ENV1**

9.3 Recommendations

It appears that Industry 4.0 could eventually disrupt the shipbuilding industry. However, further in-depth studies should be undertaken in the shipbuilding industry to analyze in which areas digitalization would cause a significant impact. There are still many gray areas because of the lack of research and also the dearth of shipyards currently investing and developing Industry 4.0 technologies. Accordingly, the studies could also be validated using theoretical sampling with industries that are more advanced in the implementation of digitized technologies, thus helping to validate the findings. Merely considering the shipbuilding industry would not be sufficient to develop understanding of the complete impact of the adoption of Industry 4.0 technologies.

It is also recommended that a prototype of the augmented reality Cyber-Physical System be developed. By having a prototype, the impacts of applying the technology can be measured and

tested. This type of approach would also help to obtain a better understanding of the applicability of Industry 4.0 technologies in the shipbuilding industry. Additionally, it is understood that the application of the related technologies could yield improvements in the construction process of shipyards. Therefore, further research is needed to investigate other applications of the technologies within a shipyard setting.

Also, because this thesis was based on qualitative research studies, using first literature review and then expert- interviews a final confirmatory study should be conducted in a form of a survey in shipbuilding companies with experience in the implementation of Industry 4.0 technologies helping to quantify and measure the direct benefits of the implementation of the related technologies. Such a study will be essential to benchmark the impact of industry 4.0 technologies for shipyards still using traditional manufacturing processes. Furthermore, other studies could involve similar manufacturing settings as the shipbuilding industry, where different factors could also be observed such as organizational structure, top management commitment, and the general steps that these companies have made towards the successful implementation of Industry 4.0 technologies.

9.4 Generalizability

Because the present thesis is based on a qualitative research based on 22 expert interviews divided in three main categories (Shipbuilding, Industry 4.0 and technology developers) the generalizability of the findings is limited and specific to the shipbuilding sector and related Industries that share the Uniqueness of their products and the requirement of accomplished craftsmanship in their manufacturing process.. Additionally, considering that the present thesis was structured using the TOE framework ,the general steps and methodology can be transferred to other studies that consider the adoption of technology within organizations that share similarities with the shipbuilding industry across the production value chain.

Bibliography

A Khan, K. T. (2016). *A survey of Current Challenges in Manufacturing Industry and Preparation for Industry 4.0.* Magdeburg: Magdeburg Research and competence cluster.

A Tornatzky, L. F. (1990). *The process of technology Innovation.* Lexington: Lexington Books.

Agbim, K. (2015). *The relative contribution of management skills to entrepreneurial success: A survey of small and medium enterprises (SMEs) in the trade sector.* International Organization of Scientific Research Journal of Business and management,.

Ajzen, J. (1991). *The Theory of Planned bahaviour.* Boston: Organizational Behavior and Human Decision Processes.

Ateeq Khan, K. T. (2015). *A Perspective on Industry 4.0: From Challenges to Opportunities in Production Systems.* Magdeburg: University of Magdeburg.

Awa H, U. O. (2016). *Using TOE framework to study the adoption of ERP solutions.* University of Plymouth: Business & Management.

Balasingham, K. (2016). *Industry 4.0: Securing the Future for German Manufacturing Companies.* Utrecht: University of Twente.

Braha, D. (2008). *Data Mining for design and Manufacturing.* Boston: Kluwe Academic Publishers.

CGI. (2017). *Industry 4.0 Making your business more competitive.* CGI Group.

CGI GROUP INC. (2017). *Industry 4.0 Making your business more competitive.* San Francisco: CG1.

Cho, K. (2008). *An Integrated Process Planning and Scheduling System.* Pusan: Anals Of CRPI.

Cognizant. (2016). *How to move from company-centric to customer centric.* MIRABEAU.

Davis. (1986). *A technology acceptance model for empirically testing new-end user information systems.* Massachusetts: Sloan School of Management.

Davis, R. (2015). *Industry 4.0: Digitalisation for productivity and growth.* Brussels: European Parliamentary Research Service.

Davis, R. (2015). Industry 4.0: Digitalisation for productivity and growth. European Parliamentary Research Service. *Sciende of reseacrh*.

Deloitte. (2015). *Industry 4.0 Challenges and solutions for the digital transformation and use of exponential.* Retrieved from http://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-

Deloitte. (2016). *Challenges and solutions for the digital transformation and use of exponential technologies.* Bremen: Deloite Corporate Finance.

Deloitte. (2016). *Industry 4.0 and cybersecurity.*

Deloitte. (2016). *Industry 4.0 and manufacturing ecosystems: Exploring the world of connected enterprises.* Deloitte University Press.

F Alatawi, Y. D. (2012). *Conceptual model for examining knowledge of management systems KMS adoption in public sector organizations in Saudi Arabia.* Brunei: Proceeding paper for GOV workshop 12(tGOV12).

Faems, D., & Looy, B. (2005). *nterorganizational Collaboration and Innovation: Toward a Portfolio Approach.* Journal of Product Innovation Management, 22 (3): 238.

H Kagermann, J. H. (2014). *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry.* Berlin: Forschungsunion.

Hadijna, M. (2009). *"Simulation modelling based methodology for shipbuilding production process design".* Zagreb: University of Rijeka, Faculty of Engineering, Croatia. Summary published in Strojarstvo (ISSN 0562-1887).

Hartog, & Veschuren. (2005). *Evaluation in Design-- Oriented Research.* Nijmegen.

Ismail V, M. M. (2016). *Aplication of TOE framework in examining the factors that influence PRE and POST adoption of CAS in Malaysian SMES.* Kuala Terengganu: International Journal of Inforrmation Technology and Business Management.

J Venkatesch, M. D. (2003). *User acceptance of Information technology toward a unified view.* Boston: MIS Quarterly.

Jensen, M., & Johnson, B. (2007). *Forms of knowledge and modes of innovation.* Research Policy. Vol.36, n.5, pp.680-693.

Jimenez, M. (2016). *What is the impact of the industry 4.0 in the process industry ?* Delft: TEBODIN Tu Delft.

Jimenez, M. (2016). *What is the impact of the industry 4.0 in the process industry?* Delft.

Joo Hock, C. G. (2015). *Smart Design for Ships in a Smart Product through life and industry $.0.* Singapore: Sembcorp Marine Ltd.

Jung, D., & C Chow. (2003). *The role of transformational leadership in enhancing organizational innovation: Hypotheses and some preliminary findings.* The Leadership Quarterly, 14, 525–544.

K Kuan, P. C. (2001). *A perception based model for the EDI adoption in small business using the TOE framework.* Boston: Information and Management.

K Zhu, K. K. (2005). *Post-adoption variations in usage and value of e-business by organizations: Cross country eviddence from retail industry.* Barcelona: European Journal of Information Systems.

Lambe, J., & R Spekman. (1997). *Alliances, External Technology Acquisition, and Discontinuous Technological Change.* Journal of Product Innovation Management.

Lee S, K. B. (2013). *Mining transportation logsfor understanding the after-assembly block manufacturing process in the shipbuilding industry.* Aplied soft computing.

Lee, J. (2004). *Discriminant analysis of techbnology adoption behavior.* Boston: Journal of computer information systems.

Lee, J., & Bagheri, H. (2014). *A Cyber--Physical System architecture for Industry 4.0 -- based manufacturing Systems.* Cincinnati: Elsevier.

Lima, P. (2018). *Succesful Digital Transformation in Industry 4.0 starts with human Operators.* Sensai: Analysis and Trends, Industryb4.0.

Lu, Y. (2017). *Industry 4.0: A Survey on technologies, aplications and open research issues.* Manchester: Journal of Industrial Information Integration.

M Brettel, N. F. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective. *International Journal of Mechanical, Industrial Science and Engineering*, 37-44.

M Brettel, N. F. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective. *International Journal of Mechanical, Industrial Science and Engineering*, 37-44.

M Eshaq, A. S. (2015). *The Effect of Top Management Support on Innovation: the Mediating Role of Synergy Between Organizational Structure and Information Technology.* International Review of Management and Business Research; Vol 4 Issue 2.

Man, D., & Duysters Gm. (2005). *Collaboration and Innovation: A Review of the Effects of Mergers, Acquisitions and Alliances on Innovation.* Technovation 25: 1377–1387.

Marko Hadijna, T. M. (2015). *SHIPBUILDING PRODUCTION PROCESS DESIGN METHODOLOGY USING COMPUTER SIMULATION.* Istambul: ISSN.

McKinsey. (2005). *The eight essentials of iinnovation.* McKiensey Quarterly.

McKinsey&Company. (2015). *Industry 4.0 How to navigate digitization of the manufacturing sector.* London.

Narula, R. (2001). *R&D Collaboration by SMEs: New Opportunities and Limitations in the Face of Globalization.* Research paper Merit and Infonomics.

NAVANTIA. (2015). *Smart Pipe System for a Shipyard 4.0.* Spain: MDPI.

P Chau, K. T. (2014). *Factors affecting the adoption of systems. An exploratory study*. Retrieved from DOI.ORG: http://dx.doi.org/10.2307/249740

Park, J. (2014). An integratedapproachforshipblockmanufacturingprocess. *Elsevier*, 17.

PwC. (2015). *Industry 4.0: Building the digital enterprise.* Retrieved from http://www.pwc.com/gx/en/industries/industry-.

R Geissbauer, S. S. (2014). *Industry 4.0: Opportunities and Challenges of the Industrial Internet.* Berilin: PvC.

Rifkin, J. (2016). *How the Third Industrial Revolution Will Create a Green Economy.* London: New perspectives quarterly.

Rio, P. D. (2004). *Analysing the Factors Influencing Clean Technology Adoption: A study of the spanish Pulp and Paper Industry.* La Mancha: University of Castilla.

Rogers, E. (1995). *Diffusion of Innovations.* New York: Free press fourth edition.

Sekaran, U. (1998). *Research Methods for Business.* West Suussex: Wiley.

Storch, R. (2007). *Ship Production.* London: SNAME.

T Oliveira, M. R. (2011). *Literature Review of Information Technology Adoption Models at a firm Level.* Lisbon: NOVA information management school.

Teece, D. (2007). *Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance.* Boston: Strategic Management Journal, 28, 1319–50.

Thompson, J. (1997). *Organizations in Practice.* New York: McGraw-Hill.

V Roblek, M. M. (2015). *A Complex View on Industry 4.0.* Kentucky: SAGE Open.

Van de Ven. (1993). *Managing the process of organizational innovation.* New York: Organizational change and redesign: Ideas and insights for improving performance.

Wade, M. (2010). *Resource base View on the Firms.* York: FSC York.

Wang, S., & J Wan. (2013). *Implementing smart factory of industrie 4.0: An outlook.* Int. J. Distrib. Sens. Netw.

Wolter, A. (2016). *Economy 4.0 and its labour market and economic impacts.* Munich: Institute of employment research.

Zhu, K. (2002). *A cross-country study of e business adoption using the technology-organizational and enviromental Framework.* Barcelona: Proceedings of the internation conference of innovation.

APENDIX I: Interviews Transcripts

In this appendix all transcription of the held interviews is presented. All of the transcripts were previously reviewed and approved by each of the experts. Table 13 presents the total list with conducted interviews including the corresponding codes.

Table 13: Expert interviews.

Name	***Code***	***Area of expertise***
Atul Bundel	A	Business Development - Digital Factory Division at Siemens
R Meyer	B	Head researcher
Benoit Gobilliard	C	Industry 4.0 solutions. GDPR missions.
Brian Rout	D	Director – Power Systems Simultaneous Engineering Capital Management Cummins Inc.
David Domingos	E	MSc Candidate (Marine Technology) TU Delft
Andrew Sparrow	F	4IR /Industry4 / IIoT / Digitization Applications
Pieter Huyskens	G	Research and Development Manager at Damen Shipyards Group
Rouzbeh Amini	H	Senior Director - Industry 4.0, IoT, Cyber Physical Systems at Cognizant
Cheng Boon Seng	I	Industry 4.0 Consultant/System Developer/Forum
Heinrich Munz	J	Lead Architect Industry 4.0 at KUKA
Jose Luis Inoges	K	Commercial Area Manager for Navy Vessels in Navantia (Shipbuilding Company)
Mario Naval Escartin	J	Digital Transformation Manager at Accenture / Industry 4.0 / Executive MBA at IESE Business School
Marlon Hiralal	M	Digital Transformation/Industry 4.0-Advanced Manufacturing/Internet of Things
Mathijs Roelohfs	N	Project Manager at DAMEN
Mike Overbeek	O	MSc Candidate (Marine Technology) TU Delft
Mikkel Sorensen	P	Industrial IoT | Thought Leadership | Internet of Things | Digital Transformation | Omnio | BizDev | Industry 4.0
Nacho Cantero Ramis	Q	Industry 4.0 expert
Jerome Pruyn	R	Director program ship design, production and operation Tu Delft.
Jacques Spee	S	Smart Industry Advisor specialized in Industry 4.0 and Digital Transformation
Vinay Solanki	T	IoT Strategy & Market Dev | MBA (IIM-A) | Founder (IOT-NCR) | IET IoT Panel
Wim Vollenberg	U	Digital transformation
Miguel Calvache	V	Production manager COTECMAR Shipyard

Appendix I.A: Encoded transcript of interview Atul Bundel.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Atul Bundel
Interviewer: Andres Torres
Datum: 05-05-2018

1. **What factors of production can be impacted when implementing industry 4.0**

In the era of cyber-physical system, we can see that in production has been shifted towards robotics, 3D printing and autonomous logistic vehicles but not only that there is big impact on Enhancing labor productivity and effectiveness but it will also affect the complete supply chain. In clear words we can say there is degree of complexity in material supply flow and production demand can be also unstable. **TECH3** There are some other variables can be like the organization structure and processes and which we can take it in the account. **ORG3**

2. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

In my opinion I think having a clear transformation strategy is the main obstacle. **TECH2**

3. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

It depends on lots of factors to give such kind of recommendation but talking in general I will say starting with IOT and data optimization can be my suggestion. **TECH1**

4. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

Due to IT 4.0 the ecosystems of companies are changing and behind that problem of lack of IT experience is one the factors. **ENV1**

5. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

Usually people don't like changes and I think somehow that also give an impression on organizations. **ORG2** While digital transformation we need to trained our organization by having some workshops with them for new skills or to make them understand how it will gone work.

6. **How can strategic alliance's help the transformation process towards digitalization?**

I will say without any strategic alliance the transformation process can become more complex to achieve somehow that's the answer of how to overcome from lack of IT experience in digital transformation. **ENV1**

Appendix I.B: Encoded transcript of interview R Meyer.

Interview over Adoption of Industry 4.0 technologies.
Respondent: R. Meyer
Interviewer: Andres Torres
Datum: 22-05-2018

1. **What factors of production can be impacted when implementing industry 4.0 technologies.**

Changes are expensive in the process of adopting more digitized processes. It may not be cost effective mainly because not to many airplanes are being build, there is not a steady line of production. **TECH3**

2. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

Communication between employees is complicated and because the system works any change can be complicated, lots of hurdles, including many regulations and certifications. Recertification's are complicated not cost-effective causes hindering. Complex process designs. Disruption makes the process vulnerable. Technology readiness also affects the process of adoption of technologies.

3. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

More than the actual culture of the organization are legal restrictions that affect the process of adopting new technologies in some countries you have to prove that it doesn't replace work places.

Strategic alliances: There are several examples of alliances or join initiatives to develop new technologies such as Robotic and open software that has been proven successful. **ENV1**

Organizations: They create new Departments or reorganize old departments, they join with start-ups, they also use consultancy to help solve specific problems. **ORG2**

Successful factors towards adopting new technologies: Companies that start this change should start with small changes looking for small success. **TECH5**

Appendix I.C: Encoded transcript of interview B Gobilliard.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Benoit Gobilliard
Interviewer: Andres Torres
Datum: 18-05-2018
Industry 4.0 solutions. GDPR missions.

1. **What factors of production can be impacted when implementing industry 4.0 technologies.**

Factors of production affected: Two main points you can increase productivity having more return over the investment, **ORG5** you can also increase quality in production, 40 different types of technologies. Provide better quality and the end to the user.

4. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

Difficulty to demonstrate the return over the investment, how are they going to get their money back. Difficult to measure this.**ORG5**

5. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

How can data security affect the adoption: industry 4.0 high level of connectivity there are real possibility of hacking or problems, security makes people reluctant it can be secure with proper planning. There needs to be standardization to include bigger players.**TECH1**

6. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

Prepare the team for a change on mind on how they do business it's difficult.
Focus first on Big data analytics, IoT and Artificial intelligence. Augmented reality.
Companies should focus on technologies that help people perform better. **TECH4**
You have to be reactive to change new way of doing business.

7. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

Organization: collaboration larger companies should organize in collaborations teams with a more divisional and matrix organization. Large structural organizations are usually reluctant to change. Change is necessary for bigger companies because they have to adopt. **ORG3**

8. How do government polices affect the adoption of Industry 4.0 technologies?

Some countries did not get into robotization, but they can use Industry 4.0 technologies to improve production process, government should make policies that encourage investors to develop new technologies related to Industry 4.0. Companies that invest in these technologies can have a reduction of tax related to their investment. **ENV2**
Small companies ask for a prove of concept, working for three to six months just to demonstrate the concept, if its ok the would buy it, in the case of smaller companies such as start-ups this is very difficult.

9. How can strategic alliance's help the transformation process towards digitalization?

Companies should work with bigger companies making strategic alliances, strategy collaboration between companies, each company providing and added benefit. They can benefit on other companies experience.**ENV1**

10. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Work on projects that the return over the investment can be measurable.**ORG5**
Internal changes in the companies are necessary when starting the transformation process, in some cases structural changes should be made. **ORG2**

It's necessary to work with people and not against them, people should focus on technologies that enhance the workers performance and not replace them. **TECH4** This can finally help the worker do a better job and to be more productive, make the best of every person to make them person.
Companies should start with smaller projects so they can show success and they can invest in other technologies, companies should stay away from big changes at the beginning, projects that can be accomplishes in a short time with a short return over the investment, focusing on one year returns maximum, people will not accept projects with higher times. **TECH5**

Appendix I.D: Encoded transcript of interview B Rout.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Brian Rout
Interviewer: Andres Torres
Datum: 23-05-2018
Director – Power Systems Simultaneous Engineering
Capital Management Cummins Inc.

1. **What factors of production can be impacted when implementing industry 4.0 technologies.**

Many, order entry, production control, inventory control, quality control, customer service, delivery.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

In a large company it can take a very long time, and consume many resources to implement I4.0 due to all the needed security protocols. Because most of our systems run internally I think security will be an ongoing challenge of I4.0

3. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

Systems upgrades and training are two key challenges. Ensuring our global sites are still able to communicate with each other and suppliers are additional obstacles.

4. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

We are looking at a number of IOT subjects. Remote diagnostics and predictive maintenance are two areas we believe we can transfer to quickly.

5. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

We use suppliers and consultants to help identify gaps and to help with transformation initiatives.

6. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption**.

If unchallenged existing culture will stagnate the adaption of I4.0. Senior management is required to sponsor and provide funding and beta sites and applications to allow for demonstration of the capability, **ORG1** benefits and realization that I4.0 will have a positive impact on the corporation.

7. How do government polices affect the adoption of Industry 4.0 technologies?

We would look for any opportunity to apply for grant money to support network development. Look for ways to work with local, state and federal government on implementing. **ENV2**

8. How can strategic alliance's help the transformation process towards digitalization?

In the security space, industry forums, connecting academia and industry to find best practice and latest technology.**ENV1**

9. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

Use all the resources available and benchmark successful industries. **ENV1** Look for industry leaders in the systems and talk with them. **ORG1** Meet with consultants and current suppliers. Identify pilot projects and assign a team with senior sponsor and funding to implement a project.**ORG1**

10. What other factors do you think play an important role in the adoption of industry 4.0 technologies in a manufacturing setting?

Having a plan for adaption across the business. Understanding where to expect the benefits, then measure the result against the expectations. **TECH2** Demonstrate early success will help to change the culture and the mindset of the people. **TECH5.** Be realistic in terms of what is possible and how your suppliers will adapt the same initiatives as you have.

Appendix I.E: Encoded transcript of interview D Domingos.

Interview over Adoption of Industry 4.0 technologies.
Respondent: David Domingos
Interviewer: Andres Torres
Datum: 23-05-2018
MSc Candidate(Marine Technology) TU Delft

1. **What factors of production can be impacted when implementing industry 4.0 technologies.**

Last minute design changes can be affected since the decisions must be taken by an individual otherwise no one would be responsible for the decision. However, industry 4.0 in cooperation with the workers can be a really good improvement increasing the construction efficiency. An example of this could be real time task distribution (in which each worker has a dispositive) in order to manage the construction in most efficient way possible.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

Ships transport a lot of goods and dangerous products (chemicals for instance). A leak of information regarding the systems of the vessel might be dangerous.

3. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

Probably adaptation of the workers to work together with modern technologies. Since ships are highly complex and most of the times different, is hard to fully automatize their construction. **TECH3** The first idea coming to my mind is the real time task distribution among the workers.

4. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

With regular courses and assessments.

5. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

If I well understood properly the question, I would say that the organizational culture can play a significant role in the adoption of Industry 4.0. **ORG3** To support the adoption might be wise to start slowly introducing the new concepts and try to steer the people to the most suited tasks. **TECH5** This might be an issue in organizational cultures with an old average age.**ORG3**

6. **How can strategic alliance's help the transformation process towards digitalization?**

Can be done by splitting the investments and the technological jump among two or more companies and them all take advantage of that and learn from each other. **ENV1**

7. **What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits**

Try to start regularly and slowly implementing it with voluntarily and regular courses for the workers. **TECH5** Adapt the company environment to that, for instance this adoption will substitute a lot of workers, try to teach them how to maintain and take care of the new systems that are being implemented. **TECH4**

8. **What other factors do you think play an important role in the adoption of industry 4.0 technologies in a manufacturing setting?**

Decision making might be an important issue because if a certain machine takes a wrong decision, who's the fault?

Appendix I.F: Encoded transcript of interview A Sparrow.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Andrew Sparrow
Interviewer: Andres Torres
Datum: 12-05-2018
4IR /Industry4 / IIoT / Digitization Applications

1. What factors of production can be impacted when implementing industry 4.0 technologies.

Shipbuilding is not doing significant volumes, materials coming in from different suppliers. **TECH3** Intellectual shortfall people are trying to use technologies but also maintain their personnel. People aspect is one of the most critical parts of the transformation two significant aspects of production perspectives can be impacted the easy way in is IoT, using sensors and actuators in a field level, using lots a production data (Temperature etc), then analyzing the data and the variables, looking at it from different perspectives, it can be easy to demonstrate the ROI.**TECH1**

2. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

Using digital twin is a huge project capturing all the data and applying to the build, extensive project management digital representation, continued life monitoring. It is a massive project that's why companies refrain from implementing this technology it is also challenging to have a short time ROI.**ORG5**

3. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Companies are afraid of security aspects, most of the IoT it is an edge ware environment so it can be kept in a local level, being very secure so this should not be a concern for companies.

4. How to assess the problem of lack of IT experience in the process of transformation towards digitalization

Take a person at a senior level and involve him with disruptive technologies, look for consultancy companies, **ORG1** look for companies that are doing similar things. **ENV1** When you have a project identified, you can organize focus groups with inter-division functions, producing MVPs, developing a proof of concept then move to a prototype to a final project or an MVP, **ORG2** some will fail, others will fail and be corrected or will be accepted. Any project that has success should have an impact in the production line and should have a provable ROI.
Problems with lack of experience on IT, the case is that you should adapt or die, from an IT perspective it's not difficult to develop an IoT without significant infrastructure level. Old machines can be taken to a digital level, **TECH1** but it does require a significant change of mentality. Projects that can be demonstrated that they actually work. **TECH5**

People are scared that machines will take their jobs, but in shipbuilding, environment volumes are low, **TECH3** so a robot is not an issue, it is critical to start from an IoT perspective, and you can model and improve the process.

5. How does the organizational culture of the organization affect the adoption of technologies related to the adoption of technologies?

it is related people are more motivated by fear that they are by gain, a position with history and reputation you do everything to protect status, new companies have less to lose, so they adapt better, but bigger companies have noticed that its necessary to adapt or die even if this is difficult and a complicated process. **ORG2**

6. How do government policies affect the adoption of Industry 4.0 technologies?

Government regulations also have a significant impact on how industries adopt these types up technologies; it has been demonstrated on how Germany, Japan and the US have adopted these technologies.**ENV2**

7. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances can be across any part of your value chain; it can help to look for similar manufacturing environments with more experience in the implementation of these type of technologies. **ENV1**

8. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Industry 4.0 should be developed at a senior high level, **ORG1** developing strategies that change the mentality of how people see these technologies. **TECH2**

Appendix I.G: Encoded transcript of interview P Huyskens

Interview over Adoption of Industry 4.0 technologies.
Respondent: Pieter Huyskens
Interviewer: Andres Torres
Datum: 17-05-2018
Research and Development Manager at Damen Shipyards Group

1. What factors of production can be impacted when implementing industry 4.0 technologies in a shipyard

This type of technology can have a very positive impact on the improvement of processes within a company, and they should focus on ways to improve workers efficiency and not to replace them. **TECH4**

2. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies in a shipyard?

This should not be a concern for companies as there are many ways of keeping the data and the information security in some cases most of the data can be managed in an interval level so the threat is actually minimal and it can be controlled.

3. What main obstacles can a company encounter when initiating the transformation process towards digitalization?

Changing the mentality of the company has often been proved to be difficult, but as soon as they understand at a senior level that the change is necessary his hurdle can be passed. **ORG1**

4. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process in a shipyard?

Fist shipbuilding companies should focus on having a complete PLM solution and then they can move to other technologies, but first, they really need to map their processes and their current condition to know what is the area that they want to improve and remove waste. **TECH2**

5. How to assess the problem of lack of IT experience in the process of transformation towards digitalization.

There is no easy way in this companies should immerse themselves in the change, but they can tackle this by developing training programs and also hiring skilled personnel that can bridge the gap between the production process of the company and the technology that is being implemented. **ORG2**

6. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

Usually, structural companies adapt better to these types of technologies as soon as they have the will to change, but they do have to go through internal changes in the companies creating division and department working on the development and implementation of these technologies. **ORG3**

7. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances are critical as shipbuilding companies can gain on the expertise of other companies with a similar process where the technology has been proven to work, this can help to make the decision. **ENV1**

8. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

Finally, companies should focus on making small changes that they can quickly demonstrate the ROI after this is done its more comfortable for them to move on to other projects. **TECH5**

Appendix I.H: Encoded transcript of interview R Amini.

Interview over Adoption of Industry 4.0 technologies.
Respondent: R. Amini
Interviewer: Andres Torres
Datum: 16-05-2018
Senior Director - Industry 4.0, IoT, Cyber-Physical Systems at Cognizant

1. What factors of production can be impacted when implementing industry 4.0 technologies.

Industry 4.0 is not a technology, but a way of thinking, Industry 4.0 can impact every aspect of production, in industry 3.0 robotics automation was designed to replace humans for machines but without harmonizing. Industry 4.0 tries to combine different elements using connectivity to reach smart factory production so that it can impact almost all of the aggregate value chain of production.

2. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

The first part is trying to understand the data that's is produced across different departments and how they can learn and further improve their processes, **TECH1** each one in a different way. Technologies can be used to use better your resources, making the process simpler. The first step is getting an insight of existing data you have a proof of concept, and you can increase your sensors, **TECH1** moving to reactive production to proactive production, the more data you receive, the more intelligent you will be making the company more flexible to adapt to change. The next step is incorporation with human intelligence through the experience and craftsmanship.
Industry 4.0 is about using your installed capacity adding sensors and data analytics to improve your process, lots of steps should be taken to reach the smart factory.
Companies analyze where are there current problems, understanding where they have more waste, **TECH2** after they are clear, companies can start making small improvements in the company to solve the mapped problems, **TECH5** they should not strive for massive changes at the beginning.

3. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Security aspects should not be a concern as there are forms to keep your data safe, and if you can prove that your data is secure, you can attract new customers that fear that their data can fall in the wrong hands. There are risks, and a lot of hurdles companies are attacked and continuously hacked, but if companies follow protocols, they can keep their information and their customer's information safe. **TECH6**

4. How to assess the problem of lack of IT experience in the process of transformation towards digitalization?

The general approach is, to begin with, a consulting company in combination with people involved with the production process in the factory**;** [ENV1] then they can work together to create solutions after you know exactly where you need the change you can start the training process of your working force, the training should not take much time.

5. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances should look at new technology development as start-ups, [ENV1] with the fast decision involving top management, [ORG1] having the right people involved and give priority, with a mentality of trying to kill your way of working with the new development.

6. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

The biggest problem is to justify the ROI, how is it saving money? [ORG5] How is it solving problems for the company, another big problem is to justify the business plan and the journey so its accepted if the business case is not strong enough it is not going forward. Best thing is to map what exactly you want to change, you need to know what specific problem you are solving, [TECH2] and it should have a low time ROI to get accepted.[ORG5]
Before a company first have to think about connectivity map there as is the situation and depending on the business case they know where to invest. [ENV1]

Appendix I.I: Encoded transcript of interview C Seng.

Interview over Adoption of Industry 4.0 technologies.

Respondent: Cheng Boon Seng
Interviewer: Andres Torres
Datum: 12-05-2018
Industry 4.0 Consultant/System Developer/Forum

1. What factors of production can be impacted when implementing industry 4.0 technologies.

The productivity can be affected but also, quality and reducing downtime.

2. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Data security is still a concern for some companies, so it is still negative as they are not guaranteeing of having 100% proven security. So, they refrain from using clouds of data. They worry about hacking; they should not use clouds for controlling machinery. **TECH6**

3. How to assess the problem of lack of IT experience in the process of transformation towards digitalization

Lack of talents on IT is a significant hurdle in the digital transformation, lack of vision and lack of determination of top leadership can also be a big problem, **ORG1** some of them don't know the benefits of the technology, so they are afraid of change, **ORG2** companies should hire people with the knowledge and train their workers.

4. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

They should focus on Big Data analytics, but first, they have to map their current process, **TECH2** at the beginning they should develop products that are compatible with their current machinery. Extracting data from their current machine and do advanced analytics and help to optimise their current process. **TECH1**
What the lack of IT experience in the company is a huge challenge, but also you should include OT, it is challenging to find workers that can integrate the new technologies with the process of the companies**,** **TECH4** so this is a big challenge. After you have people with knowledge in OT and IT, then you can integrate Industry 4.0 technologies into the company.

5. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

Organizational culture does impact the adoption of the technology; it's also a huge obstacle, SME is usually not very keen. **ORG3** In implementing new technologies as they do not have huge capitals. **ORG5** ROI also is a significant impediment for these companies as the ROI should be measured at

the need to show small times of return something that often has been proved to be difficult. Any project with an ROI of over one year is usually not accepted; this is why small changes should be implemented to demonstrate the benefits and the to move on to other projects. **TECH5**

6. How do government policies affect the adoption of Industry 4.0 technologies?

The government has a significant influence on the adoption of the challenges, they can give tax breaks to the implementation of the technologies, so it can be an important factor when deciding on implementing the technology. **ENV2**

7. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances are important as companies can benefit from others with more experience in the adoption process of industry 4.0. They need to benefit from the knowledge and the experience of others so they can have a more natural transition. **ENV1**

8. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

To guarantee a successful implementation step number one is: Form an industry 4.0 team 2) This team should receive high-level training in the technology **ORG2** 3) Draw the region and the route map of the organization and where you want to implement the technology. **TECH2** They should focus on the big picture but accomplish it through small changes at the beginning; you should not be very ambitious at the beginning you should start with small changes to move on to more significant changes. **TECH5**

Appendix I.J: Encoded transcript of interview H Munz

Interview over Adoption of Industry 4.0 technologies.
Respondent: H Munz
Interviewer: Andres Torres
Datum: 19-05-2018
Lead Architect Industry 4.0 at KUKA

1. What should companies do towards starting the process of digital transformation?

From my personal opinion companies should start collecting data from their production plant, **TECH1** these companies have lots of machines and devices but there isn't a master plan to collect all of the data that is being produced by humans, machines and processes, data from workers should be generic with no name assigned for privacy concerns, the data should be collected from sensors or devices, this data goes to a production cloud, after the data is in the cloud you can do asset monitoring, predictive maintenance, optimization and big data analytics which can lead finally to artificial intelligence.**TECH1**

2. The principal problems a company goes through when they are starting the transformation?

The most presented problems are lack of resources and lack of training. **ORG5** Another critical situation is the fact that employees usually have a very high workload, and additionally give more work to the people can this can create problems. This situation can only be solved by top management commitment to make these changes within the company, **ORG1** to invest in new technologies and hire new personnel. Changing the culture of people is often difficult because they have an established way of doing their work. **ORG2**

3. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

The culture of a company also has a significant influence on how they adapt the technology because the company needs to integrate the technology within every department of the company if the technology is not accepted in every department and integrated the Industry 4.0 technology will not work correctly.**ORG3**

4. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

When starting the transformation process companies should not start with considerable changes in their production line, **TECH5** they should start with small changes and demonstrate that the technology works if there is not a success with the implementation of the technology or the collection data it should be implemented in another sector.

5. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Security of data should not be an issue for companies there are mechanisms to keep information secure, many companies are doing this without having any problems so that you can manage your data in platforms, and the information can still be secure.**TECH6** There are ways to come over this by using experts.

6. How do government policies affect the adoption of Industry 4.0 technologies?

Government policies do affect the way companies adopt these technologies, in some cases the government pushing production companies to go into industry 4.0 using tax exemption laws. There should be laws that support SME so they can use Industry 4.0 technologies to be more efficient. **ENV2**

7. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances are important, but you should be very critical in the company you go to, so you should look for indeed specialists in the area and companies that have similar production facilities and experience with the technologies. **ENV1**

8. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Technical expertise, resources and individual support from top management in some case companies should create special departments that push the development of the technology**.** **ORG1** **ORG2** The workers should not direct the change; they need external help this help can come from consultancy companies, the creation of division or new departments… in some cases creating a small start-up to push the development of the technology. **ENV1**

Appendix I.K: Encoded transcript of interview J Inoges

Interview over Adoption of Industry 4.0 technologies.
Respondent: J L Inoges.
Interviewer: Andres Torres
Datum: 2-05-2018
Commercial Area Manager for Navy Vessels in Navantia (Shipbuilding Company)

1. How does installed infrastructure affect the process of adoption of industry 4.0 technologies in shipbuilding?

Installed infrastructure is critical there are two areas in which industry 4.0 is going to be very decisive on how shipyard will adopt the technologies, the areas are the products that are going to be designed, and another segment that will change is how ships are being made. Today with current technologies they way of making ships is going to change so the way ships are being built needs also to change. **TECH3** The way information is shared between departments will also change, work will be shared within clouds, and big data analytics tools will improve the production process of ships. **TECH1**

2. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

A shipyard should not think about the technology because there are so many technologies it is difficult to select one**,** **TECH2** they should start thinking about where they need the change, what are your actual processes and your products to make the decision. In some cases, shipyards are investing on how to improve construction process, such as 3d printing, and drones for inspection. However, companies need to go to a complete map of their current process to know where they want to go, and what they need to change to go to the shipyard of the future. **TECH2**

3. How to assess the problem of lack of IT experience in the process of transformation towards digitalization

It does not make sense to invest in new technologies if you are not doing a parallel instruction to the workers on how the technologies work and how they can help to improve the actual processes. In some cases, it will be difficult for some workers to participate in this transformation because of their age and mentality, but is something that is necessary, one way to tackle this is combined experienced workers with younger workers keener to work with new technologies. **ORG2** Its difficult to compare the shipbuilding industry because every product is unique and different from each other, so it's difficult to bring other technologies from other industries, but specific technologies can use that are intended to help the worker, so it's not about creating automation on a line of production but using technologies that help the worker to be more efficient in his job. **TECH4.**

4. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Security is a big concern of shipyards, shipyards need to maintain the security of their information and moreover, if the information is related to military products, also some clients are particular about the security requirements.[TECH6] For these reasons every new process or technology that is used has to be tested, and it has to be proven to be secure. So, there's a priority for keeping high-security standards this has to be done complying with strict protocols and working with experts in the area.

5. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

The structure of an organization is a decisive factor but the most crucial factor to know is that companies need to know or they adapt, or they die. [ORG2]

6. How can strategic alliance's help the transformation process towards digitalization?

Developing strategic alliances between shipyards is very important as they can build upon the knowledge, and the experience of each shipyard, a change of mentality should be accomplished, but nowadays companies should have more knowledge than ever, for this reason, it's necessary to work with other shipyards to have a better product and learn from each other. [ENV1]

7. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Shipyards and other companies should work together with universities to boost the development of the technologies meaning that there is a win-win situation for the universities and the companies that are gaining on the development of the technologies. [ENV1]

8. What other factors do you think to play an essential role in the adoption of industry 4.0 technologies in a manufacturing setting?

Shipyards should change the organization, so they find the best way of adopting the technologies, some shipyards have found that it has been productive to create a new department or division, their work is to direct the new projects and maintain a direct communication channel with top management so they can accept the implementation of the technologies.[ORG2]

Appendix I.L: Encoded transcript of interview M Escartin

Interview over Adoption of Industry 4.0 technologies.
Respondent: Mario Naval Escartin
Interviewer: Andres Torres
Datum: 10-05-2018
Digital Transformation Manager at Accenture / Industry 4.0 / Executive MBA at IESE Business School

1. **How does IT infrastructure hinder or boosts the adoption of Industry 4.0 technologies in manufacturing?**

IT is the enabler. The approach to test the technologies can be based on PoC. But the real challenge is the industrialization for the enhancement in production systems that usually requires the integration with backend system managed by IT.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of the technologies?**

Data Security affects to all the processes in the industry, even for non-4.0 activities. But the cybersecurity focus for I4.0 is the IoT. If all the devices are connected in order to change the activities and give the making decisions process to the machines, the cybersecurity must ensure the communications, the hardware and the software protection. **TECH6**

3. **What main obstacles can I company encounter when initiating transformation process towards digitalization?**

The digitization must be pushed by P&L criteria (revenues and costs) and the impact in the organization can be mainly found in the staff reduction. It´s necessary to manage the resources because they should leave the less added value activities. **ORG5**

4. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

Mobility (time reduction and ensure the information registration) and Advanced Analytics (including analytics in data from IoT solutions) **TECH1**

5. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

It´s a lack of knowledge but IT people are easy to adopt new technologies and subcontractors are ready to help. **ENV1**

6. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

Two possibilities

1. For largest companies, silos of transformation where there is free to develop solutions (no synergies, but competence push)
2. Transformation managed by central organization: well structured, easier to manage but could be slower which is enemy for innovation. **ORG3**

7. **How do government polices affect the adoption of Industry 4.0 technologies?**

The government must be able to push the small companies getting grants to develop the industry 4.0 and avoid losing competitiveness. **ENV2**

8. **How does competitive pressure affect the adoption of Industry 4.0 technologies?**

The success of Industry 4.0 is the real efficiency in the company (and even new business model's development) so directly must be related to. If the rest in the ecosystem can get it, the pressure increases.

9. **How can strategic alliance's help the transformation process towards digitalization?**

Non-experience on this, but there are phases in projects that can be managed in alliance. For instance, companies can share resources for PoC or Pilots to test the impact in the organizations. **ENV1**

10. **What other factors do you think play an important role in the adoption of industry 4.0 technologies in a manufacturing setting?**

Choose the right people in the organization, free to think, to develop, event make them to feel the project as their intracompany entrepreneurship. **ORG1**

Appendix I.M: Encoded transcript of interview M Hiralal

Interview over Adoption of Industry 4.0 technologies.
Respondent: Marlon Hiralal
Interviewer: Andres Torres
Datum: 16-05-2018
Digital Transformation/Industry 4.0-Advanced Manufacturing/Internet of Things

1. How to assess the problem of lack of IT experience in the process of transformation towards digitalization

Companies should focus on having a robust enterprise software with a complete integrated solution with the entire production plant.
The first step that company should deal with the transformation process is to model every process in the company to know where they can improve, **TECH2** so companies should not start thinking about technology, **TECH2** they should first think about there as is the situation and move on where you want to be. Then you can know how you can improve your process.

2. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

When starting the transformation, it is often necessary that companies focus on small progressive changes rather than significant changes within its manufacturing process, **TECH5** if something fails it will not affect the core production of the company, and it will not be a huge throwback if the technology is not successful at the beginning.

3. How can strategic alliance's help the transformation process towards digitalization?

Looking for companies with similar technologies can help to bridge the gap produced by the lack of knowledge and experience, however, before making any decision its necessary that companies have a complete understanding of their processes, this will help them understand how the other company can help them. **ENV1**

4. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Its often recommended that companies looking to start in this new technology create individual departments and divisions, **ORG2** people with specialized training in the software and the technology so they can take advantage of the benefits of the technology and enable a perfect fit with the actual production process of the company.

Appendix I.N: Encoded transcript of interview M Roelohfs

Interview over Adoption of Industry 4.0 technologies.
Respondent: Mathijs Roelohfs
Interviewer: Andres Torres
Datum: 28-05-2018
Project Manager at DAMEN

1. What factors of production can be impacted when implementing industry 4.0 technologies.

Building a ship is a complicated process as there a lot of complicated processes involving manual labor and craftsmanship of the worker, which means its sometimes difficult to change this way of work.**TECH3** Every ship that is being built, and in some cases the specifications of the ship are changed during the building the process; this leaves very small room for automation, that's why I think the shipbuilding industry is still lagging in the adoption of these new technologies. **TECH3**

2. What main obstacles can a company encounter when initiating the transformation process towards digitalization?

Shipbuilding companies are not keen on changing their way of working and doing changes the mentality is more structured as if something is working it should not be changed, this can also be a considerable barrier for adopting new technologies. **ORG2**
The unique characteristics of a shipyard worker is also an important factor that creates difficulty in standardization because every worker takes different times to finish his work, this is because usually, the work is more about craftsmanship and manual labor. Also, skilled and certified workers are difficult to find, so they also do not want their work to be measured timewise, they need their space to do their work correctly. **TECH3**

Appendix I.O: Encoded transcript of interview M Overbeek.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Mike Overbeek
Interviewer: Andres Torres
Datum: 02-06-2018
MSc Candidate (Marine Technology) TU Delft

1. **What factors of production can be impacted when implementing industry 4.0 technologies in a shipyard**

In my opinion at this moment not many factors of production can be impacted when implementing industry 4.0 technology in a shipyard. The most important reason for this is that most ships are unique and only build once. **TECH3** If you want to implement features of this I suggest to talk with one of the relative large shipyards preferably one that has series building. An example of this is the Damen shipyard.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies in a shipyard?**

I do not have much knowledge about data security, but I think cybercrime is not really a large issue in the shipyard industry. Mainly because projects are often unique and each shipyard does projects in its own way. Looking at the competition by cybercrime is not really an option.

3. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

In the shipyard industry (like many others) everything is money driven. If you can convince a shipyard owner that money can be saved using those technologies he or she will surely look into it. Mostly it will be the large investment costs that will hold shipyard owners back. **ORG5**

4. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process in a shipyard?**

Ship are complex and often unique items, in my opinion if you want to implement industry 4.0 technologies one should start small and with obvious sub parts of the ship production. **TECH5** A example could be the stiffeners on the plates, this is an relative easy and time consuming process.

5. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

I think its important for shipyards to hire staff specialized in IT in order to stimulate this process.

6. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

A shipyard usually has different teams. Examples are R/D or innovation, Engineering, Production and sales. I think there should be a link between the production team and the innovation/R&D team in order to implement these technologies. **ORG2**

7. How can strategic alliance's help the transformation process towards digitalization?

Well shipyards could hire third parties to help them optimize their process towards digitalization since most shipyards do not have much knowledge about this process. **ENV1**

9) What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

In my opinion a shipyard either needs to hire specialized staff or hire a third party to optimize this process of digitalization/implementing industry 4.0 technology's. The teams that are most affected by this are the innovation and production teams. Either way, in the shipyard industry everything is about being the cheapest in production. If one could convince shipyard owners that the implementation of industry 4.0 technologies could save money it could work. **ORG5**

10) What other factors do you think play an important role in the adoption of industry 4.0 technologies in a shipbuilding setting?

- Shipyards are originally old fashioned, this could have a negative impact on the adoption of industry 4.0 technologies. **TECH3**
- Also, many Headquarters of shipyards are located in Holland, but the production is in Asia. I have been there and those shipyards really look old fashioned. Labor is really cheap there and the rules are not so strict, that's why shipyards still use these relatively cheap ways of production. I think you should look into that. **TECH3**
- Finally, ships are uniquely build most of the time, this makes the adoption of industry 4.0 technology's difficult. **TECH3**

Appendix I.P: Encoded transcript of interview M Sorensen.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Mikkel Sorensen
Interviewer: Andres Torres
Datum: 02-06-2018
Industrial IoT | Thought Leadership | Internet of Things | Digital Transformation | Omnia | BizDev | Industry 4.0

1. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

When a company's start in the transformations companies shouldn't focus on the technologies, **TECH2** but they should focus on the business angle, if they start from a technology perspective it can fail. So, you should focus on what do you want, after this is correctly done the company can map and model their processes. They have to solve a problem but the best way it's to start something that's easy to prototype, and easy to implement after this has been done you can move on to different projects, so start with small projects that you can demonstrate an easy return over the investment. **TECH5**

2. What main obstacles can a company encounter when initiating the transformation process towards digitalization?

Not being able to demonstrate the ROI it's a very typical problem for companies, companies have established payback times, so you should develop **TECH5** business plans that can be organized within this time. **ORG5** You should limit your scope of the projects, and this can be a way of really demonstrating the benefits so they can move on to different parts of the company and after this, you can let them grow. Start with small cases show success and then move on to more significant process, this can also create different ways to use the technology across another process.

3. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

Relation with how a company is organized there is a relation with the structure; rigid structures are more accessible to create change because the order can be given quickly, pros and cons to both types of structures. **ORG3**

4. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Some companies create new department teams or focus groups on boosting the transformation, GE Bosch and caterpillar they made new division and departments, and it's helping them to change the mentality of people that work, also people don't have to be worried about having extra work while they are already very busy, so they find a way how to integrate the technologies with their

current process, so companies have to reorganize and to create new divisions to drive the projects, this has been proven to be very successful. **ORG2**

5. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances are very important when companies are going through the transformation process, they should really look for companies that they can really gain upon their knowledge, partnerships are very important and can be very powerful. **ENV1**

Appendix I.Q: Encoded transcript of interview N Cantero

Interview over Adoption of Industry 4.0 technologies.
Respondent: Nacho Cantero Ramis
Interviewer: Andres Torres
Datum: 14-05-2018
Industry 4.0 enabler.

1. What factors of production can be impacted when implementing industry 4.0 technologies.

Relisted to the aspects of production that can be impacted using Industry 4.0 technology, every aspect of production should be impacted changing every aspect of the value chain of the company, the purpose is to optimize the production processes of the company. The product should end improving their processes and be more efficient on how they work.

2. How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?

Regarding the security of the information Industry 4.0 should have high storage capacity, and high connectivity of every production process of the company, this collection of data can create specific security which means you have to follow strict security protocols, **TECH1** so you make your systems robust and secure, so if you di these steps your information will be secure.**TECH6**

3. What main obstacles can a company encounter when initiating the transformation process towards digitalization?

When starting the transformation process the most critical obstacles are changing the mentality of top management, some cases CEO are not keen on changing they also fear the considerable investment not having a clear ROI. **ORG5** Moreover, finally, is fear of change, Industry 4.0 will change every aspect of production, but people need to accept the changes. **ORG2**

4. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

It's difficult to define a specific technology for a company to choose when they are starting the transformation process because they should start mapping their current situation knowing exactly where they are and where they need to go after this is very clear**.** **TECH2** They should improve the communication process so they can transfer a significant amount of data, and then you can use technologies such as Big Data analytics and cloud information analysis to implement artificial intelligence finally. For this reason, you should concentrate on communication networks.

5. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

Related to the organization how can a company surpass the problem of lack of knowledge on IT. Its necessary to surround yourself with the right people. It's impossible to know about everything so you should really try to reach out to people with the knowledge, this can be accomplishes using consultancy companies and explain the benefits of the technologies in the company, **ENV1** looking for the way on how to train workers, explaining them that the technologies are not intended to replace them but rather to help them to be more effective. **TECH4**

6. How to assess the problem of lack of IT experience in the process of transformation towards digitalization

Industry 4.0 is made for the people, so you should focus on how the technology is going to help the workers and the company, but also because the technology is indented for the people, they should also really understand the benefits of using the technologies. **TECH4**

7. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

The culture of the company affects the adoption of the technologies because you need top management support to boost the change towards industry 4.0. so everybody in the company needs to be committed, in some cases, the rigidity of the company can hinder the change.**ORG3**

8. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

Its necessary to make changes within a company such as creating new divisions or departments that support the change, it should be supported by people with knowledge in the companies process but also new technologies. Moreover, the department can also be externally supported by consultancy companies or external experts. People should know that new job positions are going to be created but it's not about replacing current workers, this will create new job opportunities. **ORG2**

Companies should start with small changes and then move on to more significant changes when you have proven that the tech ology works. **TECH5** For this reason, you should show small success and then move to others, which means if you run into problems it will not be a huge setback. Always think first about people, and how the technology the worker to be more efficient. **TECH4**

9. How can strategic alliance's help the transformation process towards digitalization?

It's necessary for companies to look for more companies that have the expertise so they can help you to change, this is very important to analyze the company that can give you a positive aggregate value. **ENV1**

Appendix I.R: Encoded transcript of interview J Pruyn

Interview over Adoption of Industry 4.0 technologies.
Respondent: Jerome Pruyn
Interviewer: Andres Torres
Datum: 14-05-2018
Director program ship design, production and operation Tu Delft.

1. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

It's difficult to convince people they have to change because of the mentality, because they usually think that more work is going to be added even if you can clearly demonstrate that they are doing extra work. **ORG2**

2. **What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits**

A company should look at cases that can prove early success, this way you can show people that are actually against change that the technology really helps to improve process. You can assure benefits in a short time proving that it works, then you can a have a majority of people that approve the change in the company. **TECH5** It's not necessary to focus on a specific technology but how you can improve process so an early success can really help you have top management commitment. **TECH2**.

You should start change in places not core to your production line and then move on to more core work. **TECH5** It should not affect a company using cloud, first shipyards do not like to have detailed information about every specific manufacturing process some workers will have privacy concerning that not every worker has the same speed of doing their job. The data in to a certain extent is on exact on what is actually happening on the field. But it is important to collect more data to help you improve the process.

3. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

Hacking and security should not be a big issue because the data will not have start and finish, therefore even if the information is hacked it will not mean anything for another shipyard.

4. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

The culture of an organization does affect the acceptance of new technologies, the example is the German shipyards they have a strong focus on improving their processes. Dutch shipbuilding is relatively conservative on how they are doing their processes, this can hinder the process of adopting new technologies.**ORG3**

5. How can strategic alliance's help the transformation process towards digitalization?

Strategic alliances are very important on helping the process of change. Northern shipyards have been doing this for years looking for other shipyards that can help each other to have extra profit, they can benefit from the expertise of each company. Reaching out for other companies is important as they can specialize in certain areas and can jointly work on bigger projects **ENV1**

Appendix I.S: Encoded transcript of interview J Spee.

Interview over Adoption of Industry 4.0 technologies.
Respondent: Jacques Spee
Interviewer: Andres Torres
Datum: 16-05-2018
Smart Industry Advisor specialized in Industry 4.0 and Digital Transformation

1. What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?

Companies should only look for technologies but look for the opportunities and business drivers forcing you to look around; you should not only look at from the technology perspective on how you can improve the way you do business. Look what the technology can offer to the company. **TECH2** It's an iteration between bossiness constructs and enabling technologies related to Industry 4.0. However, companies should look at how to connect what they are doing physically and transfer to a digital world allowing the use of technologies such as digital twin. Technologies should focus on how to help human being with how they work or how they perform for them to be more effective. These are assisted technologies that will help human been to perform better and to have less exposure to aspects that can cause lesions, such as heavy heat objects. **TECH4**

2. What main obstacles can a company encounter when initiating the transformation process towards digitalization?

The challenges that companies face when they start the digital transformation process starts because companies do not understand the concept, and there is not a clear understanding of the concept and how it can really help the company, sometimes there is much smoke in the environment but nothing concrete, for this reason, companies should focus to understand the concept and how it can really help the company, after this companies should look at the logical steps they should take, helping to know where exactly to go. **TECH2**

3. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits

When companies are starting the transformation process, companies should start with small projects such as Machine learning that can be used without altering your manufacturing process, but it is also demanding that many companies do not have entrepreneurial approach's, so they struggle to scale up after having early success. It doesn't mean the development is going to scale up after the success is demonstrated, so the real challenge is to convince top management to accept new projects.**TECH5**

4. How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption?

The organization of a company does affect the process of adoption of new technology, so small innovation teams should be used, in some cases, it's not easy to decide if they are embedded teams or separate units, or if they should function as a business unit. In my experience, they should work as a separate unit, but you also have the problem of scaling the operation when the new technology is introduced. **ORG2**

Appendix I.T: Encoded transcript of interview V Solanki

Interview over Adoption of Industry 4.0 technologies.

Respondent: Vinay Solanki
Interviewer: Andres Torres
Datum: 16-05-2018
IoT Strategy & Market Dev | MBA (IIM-A) | Founder (IOT-NCR) | IET IoT Panel Technology.

Industry 4.0 is defined differently by IIC, by Germany, who coined this term and by other standard bodies but for the context of my responses here, I will stick to the term – smart factories or connected factories using sensors and actuators to generate some value for the manufacturing or product companies. Industry 4.0 consists of many technologies, including IOT, additive manufacturing, robots, humanoids, cyber physical systems, 5D printing, etc.

1. **What factors of production can be impacted when implementing industry 4.0 technologies.**

Production is a process which leverages multiple machines, raw material, manual and automated inputs, instructions and guidance for a smooth and continuous operation. Factors that can be impacted positively are uptime, reliability, quality, throughput, efficiency, etc. through preventive maintenance, automated quality check through sensors, ambient and temperature monitoring and control, remote monitoring and remote operations, etc.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

a. Till date, SCADA systems have ensured that data has physical partitions from the network, and hence data security is there at the expense of real time availability of data to all stakeholders. But such information security violates the basic premise of information security by information not being available. In short, industry has its reservations about data security and this can impact both the adoption and value derived negatively. **TECH6**
b. However, the potential efficiencies that can be achieved and ROI of decisions made on real time data, generated from sensors through the Industry setup will ensure adoption of IoT for industry 4.0 use cases will be rapid and data security need to be designed in both the devices or objects, in the network (communication channels) and in the data storage and data access systems. For ex: IoT device onboarding and authentication, data encryption mechanism, user authentication and data slicing and dicing based on user roles.
c. Many consortiums and Government across US have started working on providing guidelines and best practices to have common structure across all hardware covering protocols, data formats, device KEY, etc.

3. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

One key obstacle would be capability of existing machines, systems and process for upgrades and enhancements. Retro fitting new IoT or connected technology solution into an existing factory or production unit is a challenge and needs much longer time than expected
Another big hurdle is the mindset of existing managers and senior mgmt., their understanding and knowledge on latest technologies, clear cut and visible ROI on the investments. **ORG5**

4. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

As per, McKinsey Global Institute, more than 60% of all manufacturing activities can be automated with current automation technology. I would recommend attacking low hanging fruits such as preventive maintenance or remote monitoring and control which can be implemented as green field or brown field projects for existing industries and also produce quicker and clear ROI. **TECH5.**

5. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization**

It is difficult challenge, it is not just lack of IT but lack of OT (operations technologies) and the knowledge on how to bring IT and OT together. Typically, you first chalk out a plan on what you want to achieve through Industry 4.0 technology adoption in your setup and then in order to do so what skill sets you need within the organization and what you need to hire from outside.**ENV1**
Device and embedded programming is one of skill less available, there are more software programmers then embedded experts. Another is skill of systems such as PLM, SCADA, PLC, etc.

6. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

Resistance to change and adoption of solution which can result in someone becoming irrelevant or redundant is an age-old problem for adoption of any new technology. Culture of innovation vs. culture of just running the operations to continue make money creates all the difference. **ORG3**

7. **How do government polices affect the adoption of Industry 4.0 technologies?**

Fourth Industrial Revolution is expected to create up to $3.7 trillion in value by 2025 but role of regulators and policy maker is crucial for helping the industry to adopt these technologies while making sure aspects of data privacy, data security, equal opportunity, scale and implementation follow certain guidelines. Government policies such as support for technology adoption through Government driven initiatives such as “Make in India”, certification of large scale deployments by Govt. bodies, support for import and export of both technology and products, involvement in trade clearance and removing trade barrier with large trade partners and finally price and risk control

can lead to much faster and quicker adoption of Industry 4.0. Take for example Germany, which coined this term, have already rolled out Industry favorable recommendations and suggestions.

8. How can strategic alliance's help the transformation process towards digitalization?

Digital transformation or adoption of new age technology, where hardware is involved and plays a crucial role cannot be done alone. Even the technology companies selling IoT or IIoT solutions are not doing everything in house hence alliances and partnerships are key enablers to build and stitch end to end solution. Bringing the best of software, hardware and domain knowledge/expertise is must to be build a sustainable, robust, reliable and scalable solution.

9. What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?

a. Culture Change **ORG3**
b. Take Risk and make a long term investment, cannot think quarter to quarter
c. Invest small and do baby steps in terms of adoption by attacking low hanging fruits first.**TECH5**
d. Have patience

Appendix I.U: Encoded transcript of interview W Vollemberg.

Interview over Adoption of Industry 4.0 technologies.
Respondent: W Vollemberg
Interviewer: Andres Torres
Datum: 16-05-2018
Digital transformation expert

1. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

The main challenges of the transformation towards digital transformation is resistance to change, the process started by developing technologies not only for the customers but also technologies that enables workers to do their work better.
KLM had a huge benefit that the mentality change came from top management commitment so it was easy for the rest of the company to adopt the innovation.

2. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process?**

The technologies should help our employees do what they do best so they can work better and help the customers in a better way. But the technology is also used by maintenance or cargo personnel, so they can be more efficient in their work contributing at the to a better customer experience.

3. **What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies? Additional benefits**

Change in a company should come from small steps, **TECH5** KLM works within a SCRUM perspective working not only on revenue but on KPI. The benefits of the innovation should be demonstrated in some way so you can move further on other steps. Top management should believe that digital transformation can help the way of working, the technology can improve the employee commitment as you empower them with new enabling technologies.

4. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies?**

Security in the information should be a concern, KLM has always been under attack but if you take serious security protocols you can find a way to make your data secure, so there is a threat but there are ways to keep your information secure.

Appendix I.V: Encoded transcript of interview M Calvache

Interview over Adoption of Industry 4.0 technologies.
Respondent: Miguel Calvache
Interviewer: Andres Torres
Datum: 19-05-2018
Digital transformation expert

1. **What factors of production can be impacted when implementing industry 4.0 technologies in a shipyard.**

Mainly the control over the process in real time, and therefore better decisions of reassigning resources, increasing producing times can be done in order to reduce the waiting times between processes and reducing the producing cost. Also, it can give better data to analyze the process in long term. In the production side, the main advantage is to reduce the risk of losing parts and reduce the searching and handling of material time by having less inventory levels.

2. **How can data security aspects of Industry 4.0 technologies affect (Positively and negatively) the adoption of Industry 4.0 technologies in a shipyard?**

There is a risk of losing key information of the shipyard, but it can be controlled with good security protections, that are available nowadays.

3. **What main obstacles can a company encounter when initiating transformation process towards digitalization?**

The advantages for implementation a digitalization strategy are difficult to calculate because they are based on saving times in the planning and controlling processes, and also a potential improvement for future projects, becoming to very subjective calculations. So in financial terms, is difficult to property convince the top managers that the investment in this technology will have a short Return-On-Investment period, but when there is a deep understanding of the potential and benefits of this technology, it can be easy to make the decision of investing in this field. **ORG5**

In the shipbuilding industry particularly, there is a bigger barrier because for many decades this industry sector has been considered as difficult to automatize due to the fact that the batch size of produced ships is low, **TECH3** and the engineering information is developed almost in parallel with the construction. However, even that this fact is true, nowadays there are many technologies to acquire, analyze and extrapolate data that even lean principles used in mass production can be replicated with a proper technology investment.

Shipbuilding has been also considered traditionally considered as an non-Lean industry and the pieces are produced in a push system, having huge levels of inventories without a real control, and making the controlling over the production process very difficult and cost demanding by making it manually. However, technologies of very low cost can reduce most of those problems by

property tracking the material flow of the pieces and the assignment of tasks to the work groups. **TECH3**

4. **What type of Industry 4.0 technologies would you recommend a company to invest first when starting the transformation process in a shipyard?**

The first thing to implement is the technology for reporting the production process, with user-friendly stations for workers to inform the progress on the assigned tasks. It also allows to report problems with materials or information with the software behind to be integrate it with the workshop planning. Once this process and organization has been stabilized, it can be go to the next level with the data acquisition directly from the machines PDA (Production Data Acquisition) with a link to the ERP through an MES (Manufacturing Execution System). **TECH1** In this implementation, should consider a principle that stands "the automatization of an efficient factory will increase its efficiency, and the automatization of an inefficient factory will increase its inefficiency".

5. **How to assess the problem of lack of IT experience in the process of transformation towards digitalization.**

The IT support in the shipyards must be divided into the traditional approach with personnel to support the web network, computer maintenance and so on, but also nowadays is necessary to have a specialized IT group to support the specialized software for design, planning and production. **ORG2** This group must do the support to the problems that occur, but also develop customized tools for the particular shipyard, in order to connect the advantages and characteristics of the software with the procedures and knowledge in the company.

6. **How does organizational culture affect the adoption of Industry 4.0 technologies and what changes should be done in the organization to support the adoption.**

The organizational culture will affect positively or negatively the implementation of these technologies whether it has been focused to reduce the different kind of waste, mainly non-productive times and if they value the time of the workers in a big manner. If this is not the situation, first the organizational culture must be convinced of this principle before any implementation of technologies. **ORG3**

7. **How do government polices affect the adoption of Industry 4.0 technologies?**

They can influence positively if they make taxes reduction for the importation of these technologies in the cases where they must be bought from other countries. **ENV2** Also, these technologies have a bigger impact when are implemented not only in the shipyard but in the maritime cluster around that support the whole supply chain, and this can be levered by the government with proper policies.

8. **How can strategic alliance's help the transformation process towards digitalization?**

The shipyards must be focused in the core of the business, and the implementation and support of IT technologies must be made hand in hand with an expert in that issue, in the long run with a strong strategic allied. **ENV1**

9. **What general recommendation would you make to a company to ensure a successful implementation of Industry 4.0 technologies?**

Make one step at a time, but with a proper vision of the final goal since the first beginning. It is not time anymore to think about these technologies as something futuristic, actually they are something from the past that it is happening in many other industries and shipyards currently, and if this is not implemented in the short term, it can be too late to recover and become a proper competitor to the others that are working and investing on this field.

10. **What other factors do you think play an important role in the adoption of industry 4.0 technologies in a shipbuilding setting?**

Any technology to implement must be seen as something that will improve the process and will reduce the manual administrative work load. However, many times these technologies give all the required characteristic and functionalities, but are not user-friendly and at the end become totally the opposite, requiring more time or even people to feed the required data, letting no time to analyze the results and making strategic changes to the company.